CONCRETE

FOR INDUSTRIAL BUILDINGS AND GARAGES

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and
GARAGES

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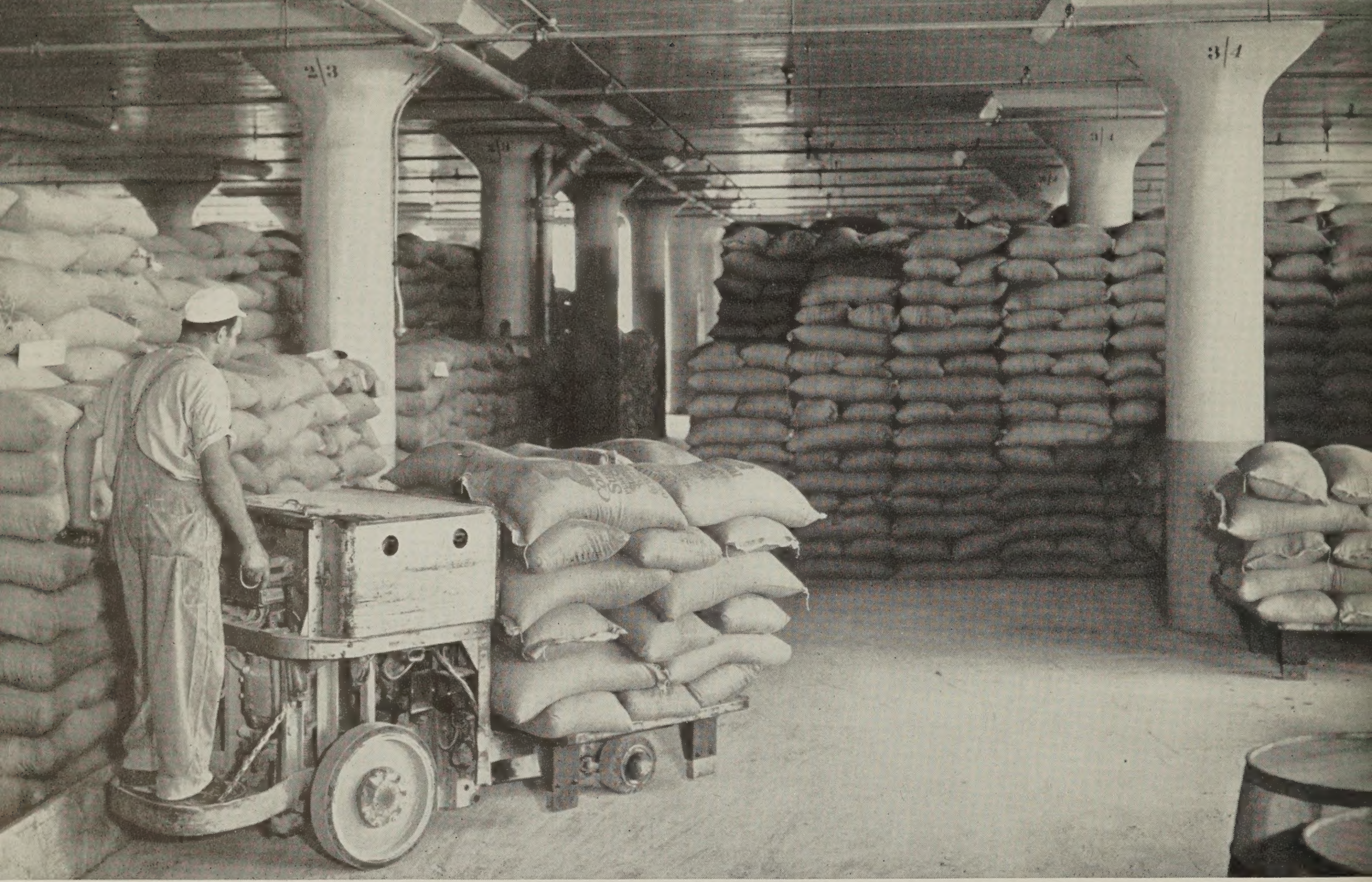

Bags of sugar stacked nearly to the ceiling in the Wm. Wrigley Jr. Company plant, Chicago, illustrate the ability of flat slab concrete construction to carry extremely heavy loads.

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advantage of insuring watertightness in the joint if the water level is near or slightly higher than the level of the floor. Where any appreciable head of water is anticipated, a metal water stop should be incorporated in the joint.

At interior columns, the basement slab is generally laid on top of the footing cap as illustrated in Fig. 2.

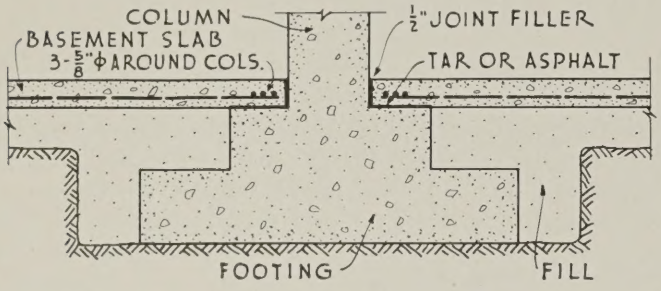

Fig. 2. Concrete slab on fill showing detail at column footing.

A mop coat and a joint filler are recommended at interior columns for the same reasons as for wall footings. Extra reinforcement is placed in the slab adjacent to the column in order to minimize cracking that otherwise may extend from the edges of the hole through the basement slab.

The top of footing caps may of course be below the bottom of the slab, and in this instance the mop coat is unnecessary but the joint filler and the extra reinforcement remain as shown in Fig. 2.

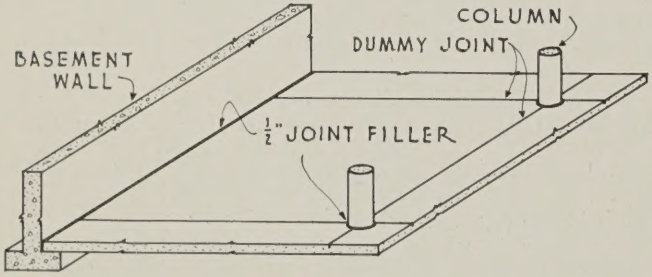

Fig. 3. Arrangement of dummy joints in slab on fill.

Fig. 3 illustrates a basement slab laid on fill with a ½-in. joint filler placed along the wall and around the columns. Some slabs have shown a tendency to crack along the column centerlines. The cracks entail no hazards but may be unsightly. They may be confined to certain positions and concealed by means of "dummy" joints placed on column centerlines. The dummy joint in this design is a ½-in.-deep "cut" in the floor surface. It may be used with even better result if the dummy joint is also a construction joint as shown in Fig. 4. As an additional precaution to make sure that cracking will not occur outside the joint, part of the reinforcement may be stopped at the joint and a wood strip provided at the bottom of the joint. Cracks in the joints are straight and concealed in the bottom of the groove. If desired the groove may be filled with mastic.

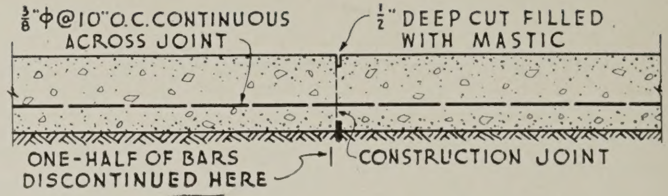
3/8"φ@10"O.C.CONTINUOUS ACROSS JOINT
1/2" DEEP CUT FILLED WITH MASTIC
ONE-HALF OF BARS DISCONTINUED HERE
CONSTRUCTION JOINT

Fig. 4. Detail of dummy joint.

If the floor is to be insulated, the construction in Fig. 5 is recommended. The subsoil is first made level and compacted. A 2-in. concrete base is then laid on the subsoil and brought to an even surface which is mopped with tar or asphalt before the insulation material is laid on it. The slab on top of the insulation is reinforced and otherwise constructed as though it were placed directly on the ground.

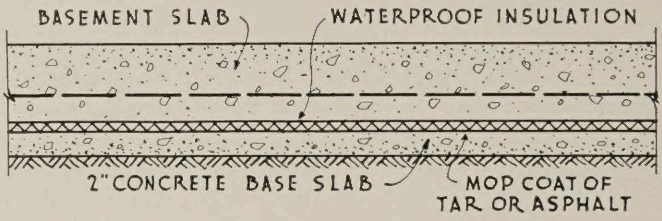

Fig. 5. Insulated concrete slab on fill.

The construction details described for basement slabs apply where the average level of the water table is even with or below the slab. If it is much higher, the ground water will exert an upward pressure—hydrostatic pressure—upon the bottom of the slab. In such instances, the slab should be designed as an "inverted" floor slab. Since the basement slab is "supported" on walls and columns, a flat slab construction*—suitably modified—is the natural solution. One type of layout is illustrated in Fig. 6 which shows the basement slab extended past the walls and under the columns. The extra depth of slab under columns serves as the "drop panel" for the flat slab construction. A waterproof membrane envelops the basement and is protected by a 2-in. base slab on the bottom and by portland cement plaster on the vertical surfaces. Another type of layout for basement slabs subject to hydrostatic pres-

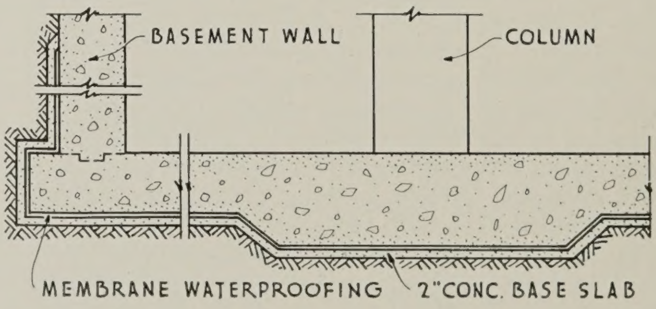

Fig. 6. Basement slab designed for hydrostatic pressure.

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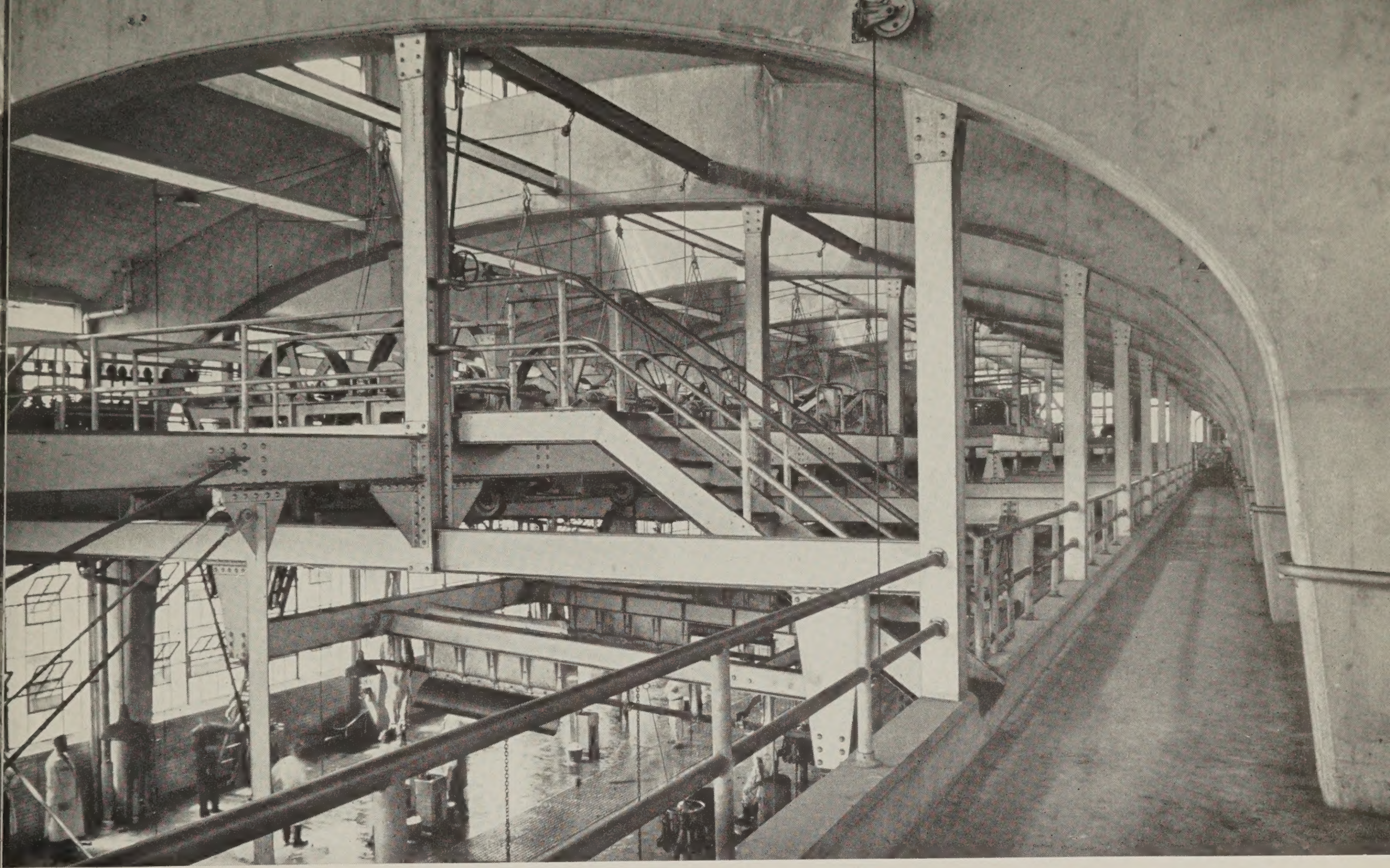
*For further details, see Section 3: "Floor Framing".



Reinforced concrete ribs carry the roof and a great deal of equipment in the beef house at Armour and Company plant in Chicago. The ribs may be described as "rigid frames with arched deck". A construction view of a rib is shown in another photograph. Designed by the engineering department of Armour and Company.

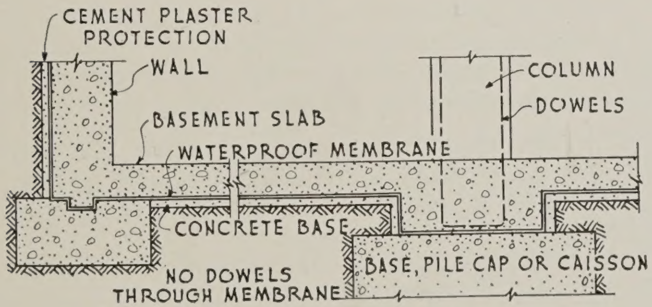

CEMENT PLASTER PROTECTION
WALL
BASEMENT SLAB
WATERPROOF MEMBRANE
COLUMN
DOWELS
CONCRETE BASE
NO DOWELS THROUGH MEMBRANE
BASE, PILE CAP OR CAISSON

Fig. 7. Basement floor and walls with waterproof membrane, columns supported on pile caps or caissons.

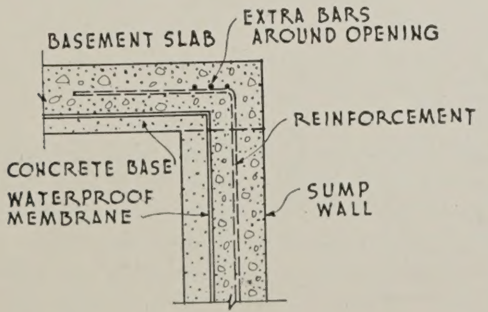


Fig. 8. Detail at sump in basement.

sure is illustrated in Fig. 7. In this case, the waterproofing membrane is laid on top of the mat, cap or caisson supporting the column. No dowels should extend through the membrane.

For prevention of leakage at "sumps" or drainage pits in basements, the detail shown in Fig. 8 is used. Note that the membrane around the sump and under the basement slab is made continuous and that extra reinforcement is provided in the basement slab around the sump opening.

Typical connection details are shown in Fig. 9 for pipes extending through basement walls. The special wall pipe fitting shown may be made even more watertight if provision is made for a joint that can be calked.

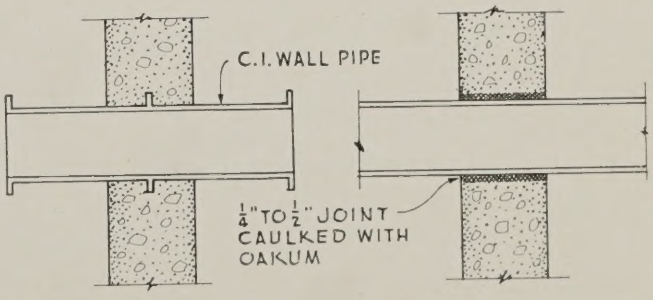


Fig. 9. Details of pipes extending through basement wall.

3. FLOOR FRAMING

The majority of reinforced concrete floors in multistory factory buildings is of the type called "flat slab" or "mushroom system". For illustration, during a period of twenty-five years since 1918 the Eastman Kodak Co., Rochester, New York, constructed 4,550,000 sq. ft. of floor area in buildings of reinforced concrete, and nearly 78 per cent of the concrete used was in buildings having flat slab floors.

The dimensions of column caps and dropped panels shown on the typical flat slab framing plan in Fig. 10 are those given in standard codes for the so-called "general case" of flat slab construction.

A building may be provided of greater width than that in Fig. 10—without increasing the panel size—by using the layout illustrated in Fig. 11. The flat slab floor in Fig. 11 is cantilevered beyond the exterior columns, and the end of the cantilevered floor supports spandrel wall and window sash. There are no columns or pilasters in the walls of a building with this type of framing, so the glazing can be continuous. The advantage of having continuous glazing can also be gained by having the wall placed just outside the exterior columns.

Framing around large openings may conveniently be made as illustrated in Figs. 10 and 11. The "beams" in Fig. 10 have a depth equal to the combined depth of slab and drop panel, which leaves the same clear height below the beams as elsewhere below drop panels in the same story. This simplifies the installation of pipes, shafting and flues on the ceiling.

The framing at the openings in Fig. 11 illustrates the use of beams with webs of ordinary shape and depth. This type of framing is not as economical as that in Fig. 10 because the deeper beam webs cut into the forms at columns. Both types of framing, however, are adequate and are commonly used.

Small openings may be placed in flat slab floors without making any special provision for framing around them. Reinforcement interrupted by such openings should be replaced by additional reinforcement of like amount placed along the sides of the opening. Referring to the upper left hand corner of the framing plan in Fig. 11 in which the customary "strips" used in flat slab design are shown, "small" openings may be described as those falling within the following maximum dimensions:

In "middle-middle" areas, openings not to be larger than one-half of the panel dimension in either direction.

In "middle-column" areas, openings not to be larger than one-eighth of the panel dimension in either direction.

In "column-column" areas, openings not to be larger than one-twentieth of the panel dimension in either direction, and not more than one opening at each column.

Openings larger than those described are also permissible under some codes without special framing around them, if provision is made for the total positive and negative resisting moments.

Cross-sections of columns in Fig. 10 are shown square in walls, but a rectangular cross-section is substituted for the square one when required in order to make the clear width between wall columns equal to dimensions of one of the standard window sash. Interior round columns are cast in forms made of sheet metal. In general, the diameters should be in even inches for column shafts and in whole and half feet for column capitals.

Marginal beams may be made wide and shallow as illustrated in Fig. 10. The beam width is optional, but it is often desirable to make the width uniform throughout. The form construction is then simplified, and the straight offset in the ceiling just inside the wall makes a convenient place for installation of a metal casing with removable cover designed to carry electric con-

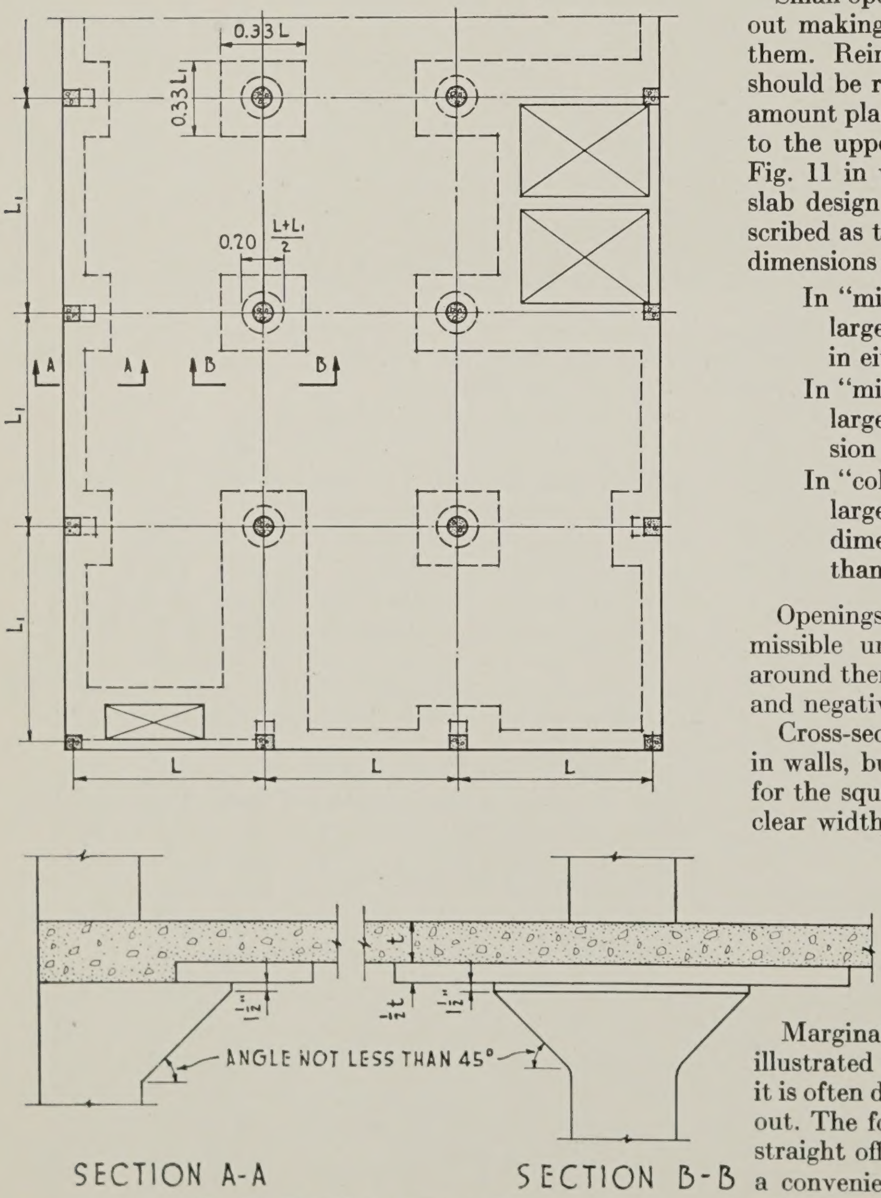


Fig. 10. Flat slab framing plan.

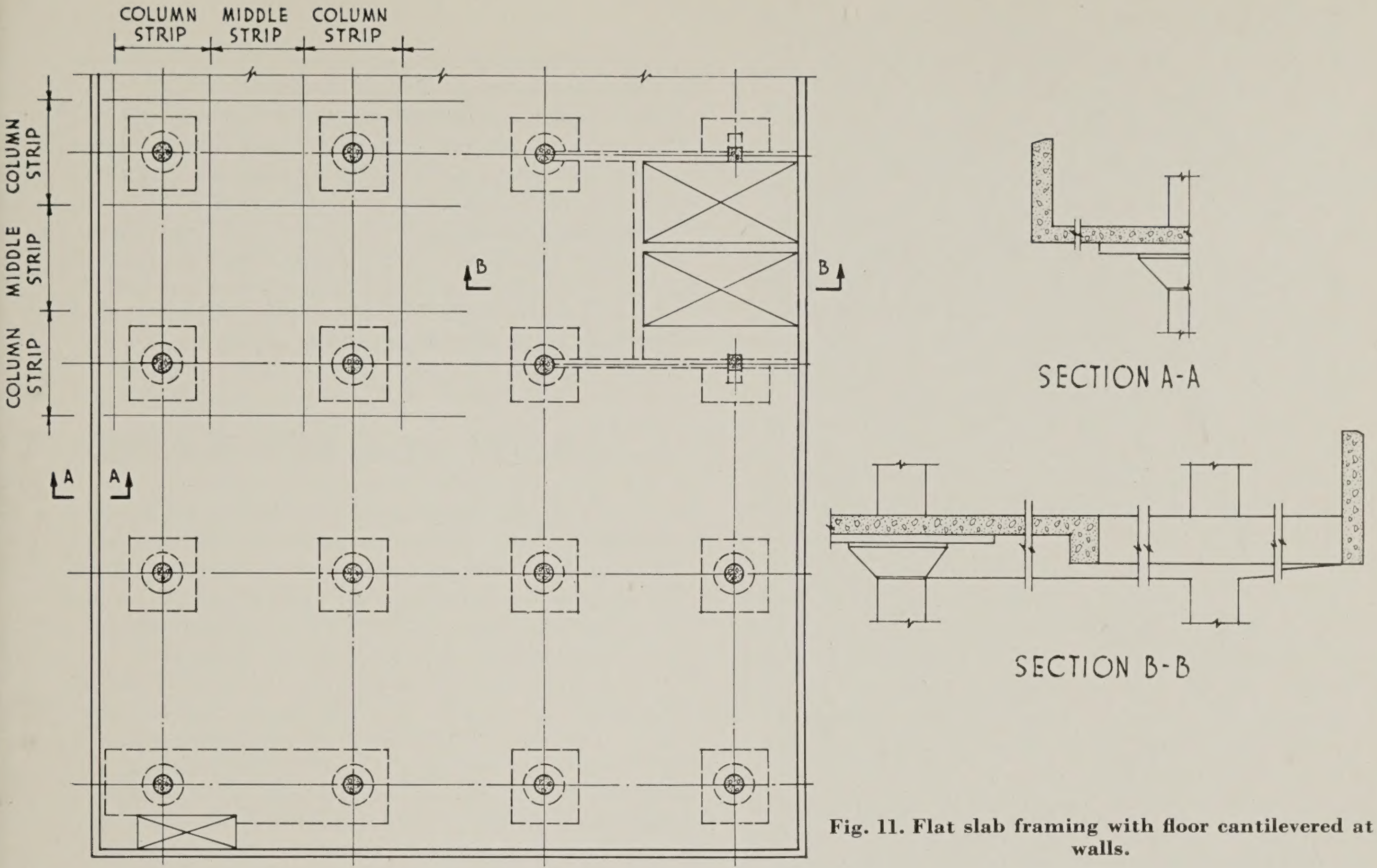


Fig. 11. Flat slab framing with floor cantilevered at walls.

duits. It is recommended not to carry window sash all the way down to the floor, but to stop it at a sill about 3 ft. above the floor. Window sash below this level adds little or nothing to the illumination and is subject to breakage.

Many factory floors are framed as illustrated in Fig. 12, in which the column layout is identical with that for flat slab framing in Fig. 10. The floor is a solid concrete slab with reinforcement extending in two directions, and each slab panel is supported by beams on all four sides.

It has been customary to construct the beams with the ordinary type of deep webs; but the shallow, wide webs illustrated in Fig. 12 have several advantages, especially for factory buildings. Column forms are simpler to construct since they are usually of plain prismatic shape without any beam cuts.* The slab span may be taken as the clear distance from face to face of

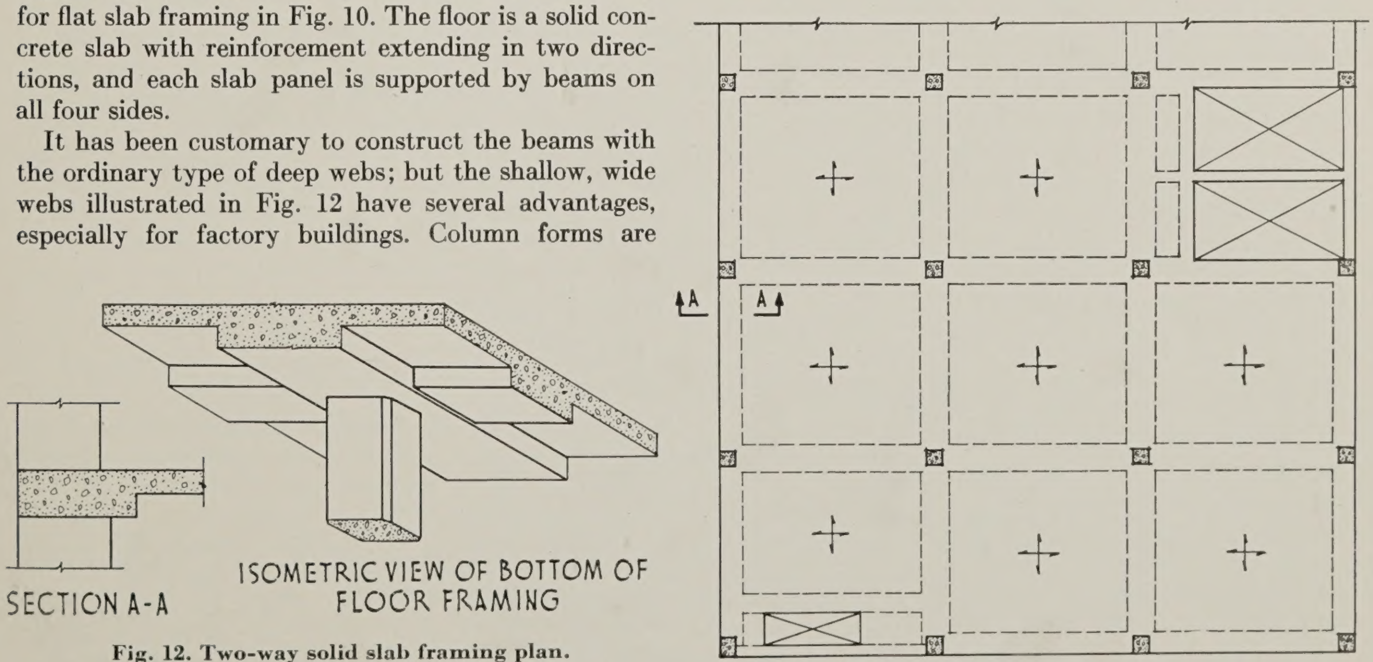


Fig. 12. Two-way solid slab framing plan.

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*In some cases, i.e., where there are large unsymmetrical live loads, it may be necessary to haunch the beams in order to transmit the moment into the columns.

beam webs and is therefore reduced when the web is made wider. Shallowness of the beam webs facilitates the installation of sprinkler pipe and other ceiling equipment, and the shallow webs cast but little shadow on the ceiling which therefore gives good reflection of daylight from the windows.

When solid two-way slab framing has wide, shallow beams it is in many respects similar to a flat slab framing not only in structural action but also in regard to performance. The formwork is simple and the ceiling presents a flat surface for attachment of equipment. Both types possess admirable sturdiness and ability to carry heavy loading and vibrating machinery. The shallowness of two-way floor construction with wide beams reduces story height which results in lower cost of walls, columns, elevators, stairs, pipes and ducts. The large flat ceiling surfaces provide excellent reflection of light, especially when painted white, and good illumination is essential in factory buildings.

The type of concrete floor illustrated in Fig. 13 known as "beam and girder" framing, is well suited to conditions in factories. A slab thickness of 4½ in. including concrete finish is sufficient for the best type of fire resistant structure.* There is generally a beam on each column centerline across the building and two intermediate beams.

The floor in Fig. 13 is shown cantilevered beyond the exterior columns. This serves to reduce the beam span and makes it possible to take advantage of continuity over exterior columns, thereby reducing both the column and beam moments as compared with the more conventional layout with columns in the exterior wall. Neither the cantilever nor the regular column layout shown are essential features of "beam and girder" framing, of which there are many modifications. In fact, one of the advantages of "beam and girder" framing is its adaptability to irregular column layouts.

Openings may be provided almost anywhere outside the webs without changing the framing. Ceiling inserts for attachment of equipment are generally placed in soffits of webs.

4. CHOICE OF FLOOR FRAMING

Three types of floor framing commonly used in factory construction have been illustrated and described in Section 3. The designer making a choice of floor framing for a specific job will consider numerous items which may be classified in the three groups: architectural layout, structural requirements, and cost.

Important items in connection with architectural layout are openings for stairs, elevators, chutes, ramps, or for mechanical equipment extending through more than one story. It is possible that the number, size and arrangement of openings may cut up the floor slab to such an extent that a beam and girder layout becomes the best choice. In other instances, one or more columns must be omitted or offset and hence require the use of long span girders or transfer girders. Variations

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*See Section 11: "Fire Resistance Requirements".

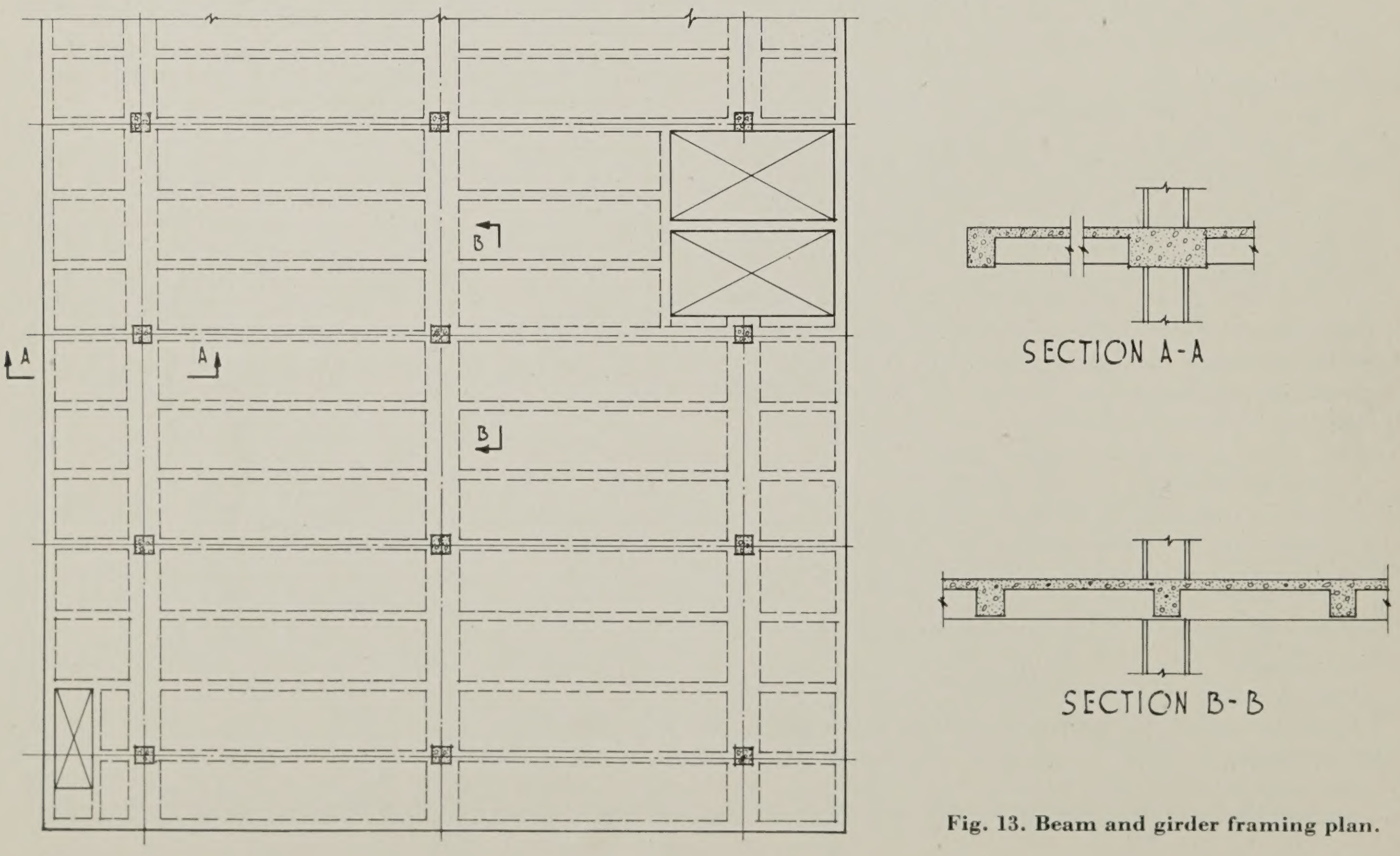


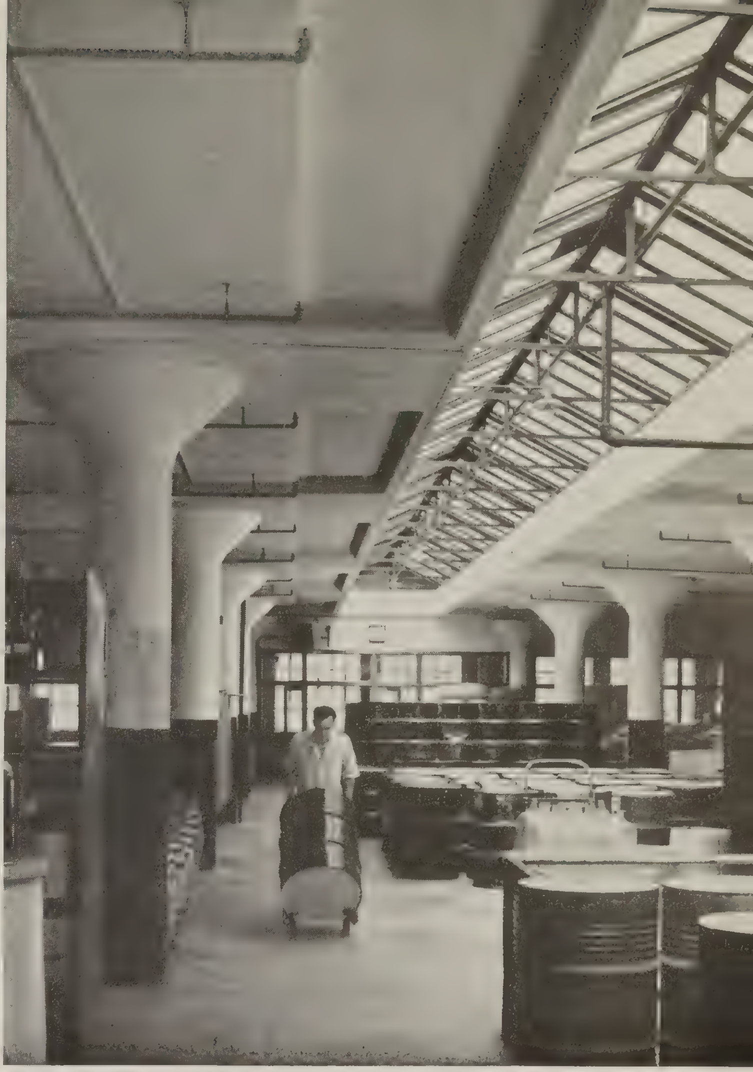
Fig. 13. Beam and girder framing plan.

in floor level in the same story, depressions or pits in the floors together with other similar details, all tend to interfere with the economical layout of flat slab. In such cases, there is advantage in using metal pan and girder framing for light loadings or beam and girder framing with solid slab for heavier loadings. These floor types also give a satisfactory solution to the framing problem where the column arrangement is irregular, as for example, where the column spacing is much greater in one direction than in the other. If the ratio of long to short span of a panel is gradually increased beyond one and one-half, both flat slab and two-way slab framings lose much of their economic advantages.

Structural requirements that have an important bearing upon choice of framing include, first of all, the type of loading. The lighter the superimposed loads the more economical will be a metal pan floor slab supported on beams or girders, while the flat slab will show more economic advantage for heavier loads. The beam and girder framing with a solid slab occupies an intermediate position. For support of vibrating loads, floors with a considerable amount of dead load are especially well suited, and slabs reinforced in two or in four directions are often preferred for support of large concentrated loads. The designer must often give thought to the relative economy of floor framing types as they are influenced by the structural requirements in municipal or other building codes. For illustration, design requirements for two-way solid slab may differ in two codes with the result that this framing compared with, say, flat slab may be more economical in one case than in the other. The choice of framing may likewise depend on whether or not it is necessary to design the structure for hurricane exposure and earthquakes. It is possible that horizontal loading may require that vertical bents be designed as rigid frames composed of columns and beams or girders. If so, a beam and girder framing is preferable, and the girders should be deep rather than shallow.

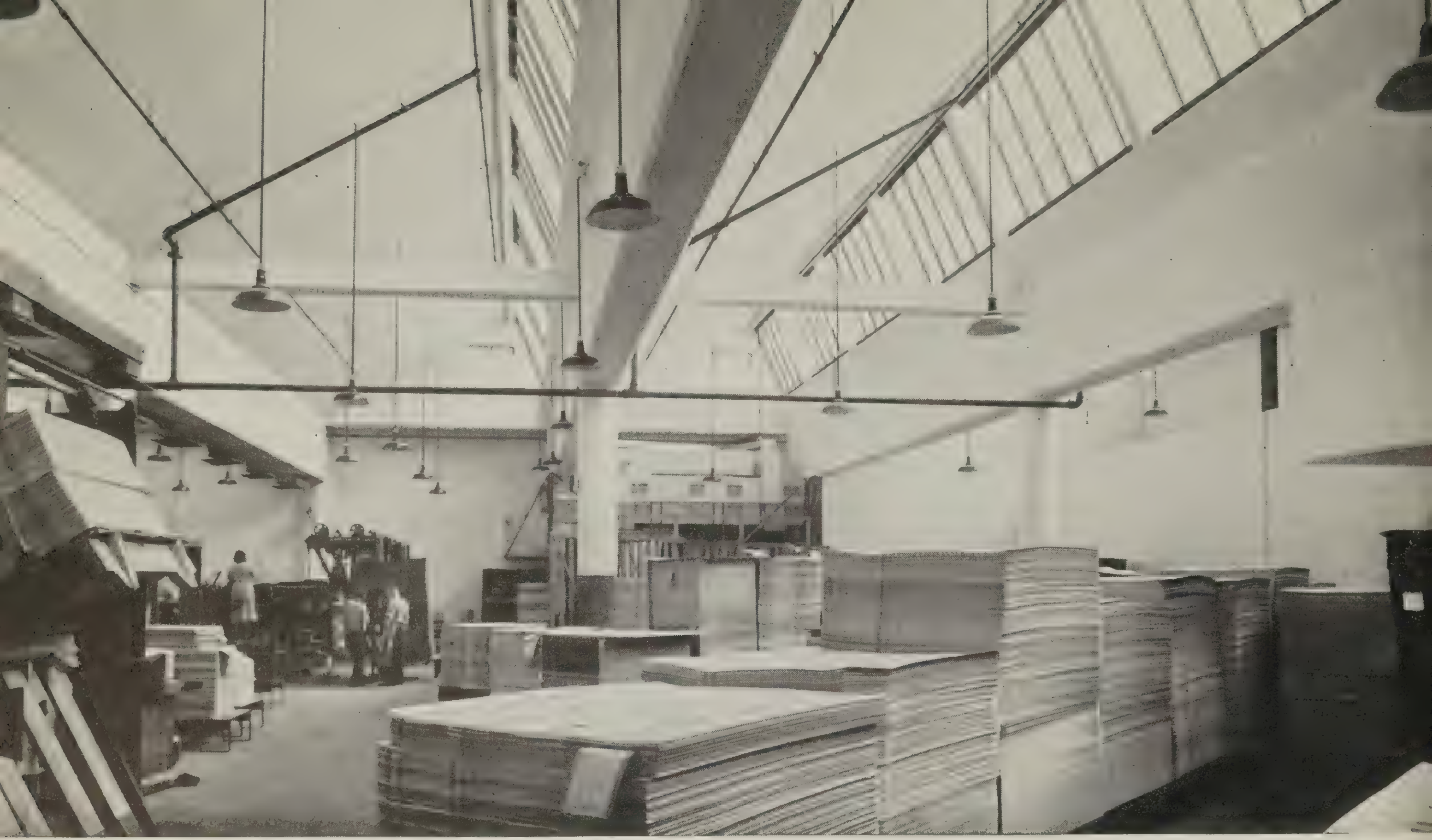
The question of cost is a major consideration during practically the entire period of planning and designing. One of the very first functions the designer frequently performs is to advise the owner on the shape, type and general arrangement of the structural layout which can be built and operated at the lowest cost and yet fulfill the industrial requirements. This problem must be considered *before* drawing formal plans, and other related studies must be carried out beyond that period. The customary procedure followed in making cost studies will be discussed briefly.

First of all, the designer investigates problems in regard to width and height of structure to be built as well as to spacing of columns or size of panels. Important factors influencing the choice of width of building are requirements for day lighting, as discussed in Section 3, and also cost of wall construction in terms of dollars per cubic foot of volume of the building. This unit cost of wall decreases with increasing width, but for factory buildings, the rate of decrease becomes small for widths in excess of approximately 80 ft. Widths less than approximately 60 ft. are not economical from the viewpoint of unit cost of wall construction. If the shape of the building plan differs from a rectangle, the question of unit wall cost must of course be studied carefully. The effect of building height upon cost is not generally very pronounced for structures between three and eight stories high. From eight stories up, the cost per cubic foot rises, but rather slowly. However, it is difficult to give general rules because factors such as type of foundation and requirement as to wind pressure design may be important variable elements in the cost analysis.



Flat slab with a long opening for a skylight placed along the middle of a bay makes an excellent roof construction in the Walgreen Company plant in Chicago. The flat slab is cantilevered beyond the adjacent columns and extended to support the edge beam around the skylight. Designed by A. Epstein.

The spacing of columns cannot be chosen solely on the basis of cost analysis. In garages, for illustration, fairly uniform standards exist which leave little or no choice as to where columns can be placed. And even in manufacturing plants, the number of bays is generally chosen as an odd number in order to provide for a center aisle, and this will of course tend to impose rather narrow limitations on the column spacing or panel size. Very small panel sizes are uneconomical. The minimum cost will in many cases prevail for panel



A saw-tooth type of roof of reinforced concrete is supported on 50-ft. span continuous girders spaced 20 ft. apart in the Chicago Carton Company plant. The beams are braced horizontally by small reinforced concrete struts. The use of form lining and white paint on concrete surfaces gives a light and attractive appearance. Designed by A. Epstein.

sizes approximately 16 ft. in both directions, but economical construction may be obtained for much larger dimensions. This phase of the cost problem is often affected by rulings and limitations imposed by local building codes and by the amount as well as the type of live load for which the floor is designed. Practically every new site and layout contain different features and require individual study.

After the general outline of the building has been studied from the viewpoint of cost, the next step is to eliminate all those floor types that are obviously ill suited to the requirements. The number of floor designs that remains for factory construction seldom exceeds three, and typical panels of these, including columns and footings, are then designed in order to arrive at comparative cost figures.

There is often an important step left before the preliminary cost study can be considered complete. Other items must be studied and included such as costs of sprinkler system, insurance, upkeep and maintenance. They may be omitted from the cost analysis only when comparison is made between designs of similar characteristics and identical fire resistance ratings.

It is frequently difficult to obtain reliable data on unit costs for comparative study, and it is therefore necessary that the estimator should possess high engineering ability, wide construction experience, and good knowledge of local conditions.

5. DIAGONAL ARRANGEMENT OF COLUMNS

A comparison is made in Figs. 14 and 15 between two types of column layout for a building that is 66 ft. wide between centerlines of exterior columns. Fig. 14 represents the conventional type of layout, but the layout in Fig. 15 is sometimes more advantageous.

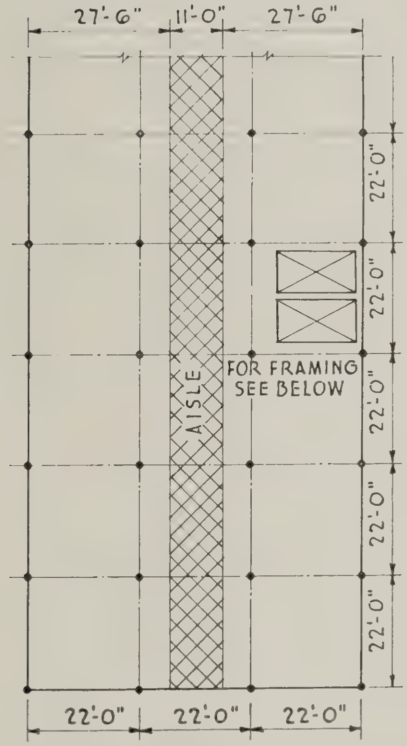
In many instances, the production layout requires an aisle down the middle of the floor, and the aisle seldom needs more than 10 to 12 ft. clear width. The column arrangement in Fig. 15 suits this type of layout excellently. The columns along the center aisle are not only *outside* the actual working area, but they also serve the useful purpose of marking the boundaries of the aisle.

There is only one row of columns extending through each working space in both layouts, but the diagonal column arrangement is the more advantageous of the two shown. Its longitudinal column spacing (26 ft. 5 in.) is 20 per cent longer than that in Fig. 14 which is only 22 ft., and yet the panel length (18 ft. 8 in.) is 15 per cent smaller. This means a considerable reduction in cost in the diagonal layout.

In addition, the load for which interior columns are designed is about 40 per cent greater in Fig. 14 than in Fig. 15, that is, the diagonal layout requires column sizes that are considerably smaller than those in Fig. 14. Summing up, the diagonal arrangement is seen to have certain advantages for layouts requiring a center aisle.

In construction there is but little difference between the two layouts. The construction of forms and the placing of reinforcing bars are essentially alike in both cases if the four-way system of reinforcement is used, but the diagonal arrangement works equally well with the two-way system of reinforcement. Drop panels, if any, in Fig. 15 may be constructed with their sides parallel to the walls. Figs. 14 and 15 also illustrate details of typical framing around large openings, which is essentially the same in both layouts.

In a building with a width, B, the column spacing in Fig. 15 is $\frac{B}{5}$ in the transverse direction, but the longitudinal spacing may be made somewhat longer or shorter than the transverse spacing.



ONE COLUMN FOR 27.5 x 22 =
605 SQ.FT. OF WORKING SPACE

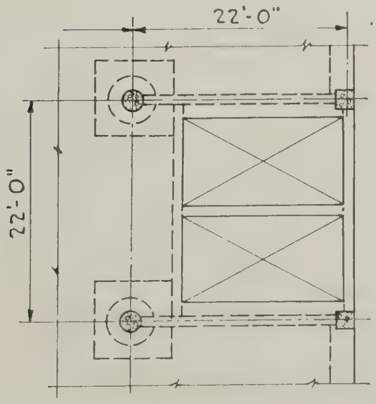
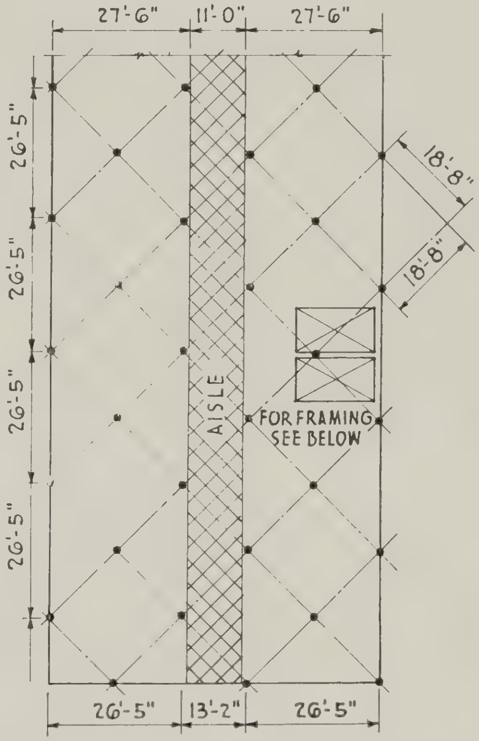


Fig. 14. Conventional arrangement of columns.



ONE COLUMN FOR 27.5 x 26.4 =
725 SQ.FT. OF WORKING SPACE

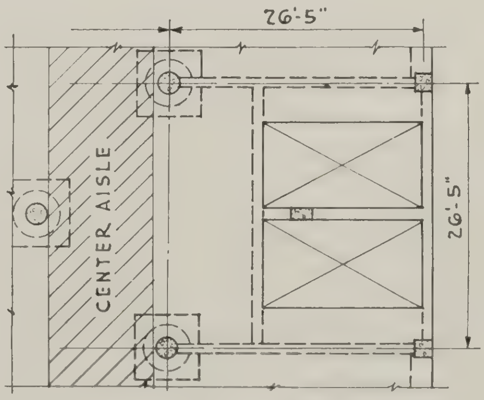


Fig. 15. Diagonal arrangement of columns.

6. LIVE LOAD, STORY HEIGHT, BUILDING WIDTH

The superimposed load, or live load (L.L.), for which a factory floor should be designed deserves careful attention. Some designers have used as little as L.L. = 75 p.s.f., but as a general rule, this low value is not satisfactory. By thus limiting the load capacity, a small initial saving is effected, but the structure is rendered useless for other occupancies with heavier loading.

The great majority of manufacturing processes can be accommodated when the design is made for L.L. = 150 p.s.f., a loading which is recommended for general use. Cost studies indicate that increasing the live load from 75 to 150 p.s.f. adds approximately 15 per cent to the cost of flat slab construction, including floor, columns and footings. The smallness of the cost increase is well justified by the considerable resale or rental value of the heavier design. Structures intended for storage may have to be designed for loads higher than 150 p.s.f.

The story height should be adapted to the nature of the product and to the needs of the manufacturing process, but ceiling heights are seldom less than 12 ft. This dimension may be increased to 14 ft. where overhead cranes are used and to 16 ft. in order to accommodate mezzanine construction.

The height from floor to window head, H, has an important bearing on the width of the working area, W. In Fig. 15, W is the dimension of 26 ft. 5 in. shown on either side of the center aisle. Excellent daylight illumination will exist over the entire width W, if $H =$ 0.4 to 0.5 times W. The smaller value of H may be used when windows extend the full width between columns and when the ceiling has plain surfaces painted white. For illustration, consider a building 75 ft. wide between centerlines of exterior columns with a layout as in Fig. 15. The value of W is $75 \text{x} \frac{2}{5} = 30$ ft., and $H =$ 0.4x30 ft. = 12 ft. The story height is then equal to 12 ft. plus the depth from window head to floor surface, which equals about one foot for flat slab construction laid out as in Fig. 15.

7. FLOOR FINISHES

The floor finish plays an important part in the successful operation of a factory. Basic requirements are that an ideal floor finish should be economical, resistant to wear, impervious, sanitary, fire resistant, skid-proof, inert, and easy to maintain and to keep clean. Concrete is the material used most frequently for floor finishes because it can, if constructed according to correct specifications, fulfill all these requirements.

Concrete finish in many factories with constant traffic by steel wheeled trucks is subject to more severe wear than is concrete in road and bridge slabs. This emphasizes the importance of laying concrete floors without any stinting on material, or on labor, and in strict observance of the rules for good construction proved by experience and tests.

For factory buildings the two-course type of concrete floor construction is recommended. The base or structural slab is laid first and struck off to a reasonably true level not less than 1 in. below the required finish grade. Before the concrete has hardened, all laitance must be removed by brushing the surface with a wire broom so as to leave the coarse aggregate exposed. This surface is cured for at least 5 days, after which the top may be placed whenever convenient.

Several reasons exist for postponing construction of the top course, especially in multi-story buildings. Immediately after the structural concrete floor has hardened, carpenters may begin placing shores and forms for the floor above. The speed of erection that can be attained in reinforced concrete construction would be impeded if erection of formwork had to wait until the wearing surface was placed. If the finish and structural base were placed simultaneously, it not only would slow down progress on the structural work but the finish would seldom get the proper protection and curing. The finish can be protected more effectively against sun, rain, freezing and unavoidable construction damage if it is placed *after* the structural concrete work has been finished and the walls have been built.

Just prior to placing the top course, the base surface is thoroughly cleaned by scrubbing and left soaking wet, but all free water must be removed. A thin coat of portland cement grout is then broomed into the surface a short distance ahead of placing of the top course.

In placing the top course, exceptional care should be given to selection of materials, mixing and placing. Fundamental principles of concrete making are the same whether applied to floors or to ordinary structural uses, but to obtain most successful results, concrete finishes for heavy duty must be laid in accordance with special, simple rules. A detailed description of these rules is given in the booklet entitled *Concrete Floor Finishes** but the major points will be described briefly.

The basic requirement is that strong and tough, coarse aggregate of suitable wearing qualities (trap rock, granite, quartzite) must be distributed uniformly throughout a dense, impervious portland cement mortar. In finishing the surface, operations must be carried out so that the coarse aggregate extends clear up to the top where it can take the wear from the traffic. Under no circumstances should the paste be brought to the surface in such amount that it—and not the coarse aggregate—is subjected to the wear. This objective is essential and is attained largely by the following procedure.

The mixture should be made with approximately 5 gal. of water for each 94-lb. bag of cement. Moisture in the aggregate must be deducted from the 5 gal., the

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*Numerous references on specific related subjects will be given to other publications available free in the United States or Canada upon request to Portland Cement Association.

The center aisle in the Chicago Carton Company plant sustains heavy wear from constant trucking. Concrete floor finishes give good and enduring service under practically every condition of wear. Note the air-control equipment suspended from the roof which is of concrete construction as illustrated in another photograph.

balance being water to be added. All the aggregate should pass the ½-in. sieve. Not more than 5 per cent should pass a 100-mesh sieve, and not more than 15 per cent should pass a 50-mesh sieve. In short, the aggregate should be well graded but rather coarse. The mix will usually be between the proportions of 1:1:1½ and 1:1:2. This mixture is placed, screeded and compacted with rollers or tampers. The concrete mixture is so dry that many contractors prefer to float it by use of power driven floats rather than by handfloating. The floating is followed by troweling after all water sheen has disappeared. Curing for at least 7 days is an essential requirement for concrete made with normal portland cement. When high early strength portland cement is used, 3 days' curing is considered adequate. If the foregoing rules are followed and the wearing course is otherwise placed as outlined in specifications in *Concrete Floor Finishes*, the floor will stand constant traffic by hard wheeled trucks without dusting or appreciable wear.

Terrazzo floor finishes are used in entrance halls and elsewhere where especially good appearance and pleasing patterns are desired in addition to the ordinary desirable qualities of a concrete floor finish. Specifications for terrazzo floors are given in *Concrete Floor Finishes* in which two standard methods of laying the floor are fully described.

Where a special non-slip finish is desired, the floor may be given a "coarse-grained" surface by brooming with a hair brush, or non-slip aggregate may be mixed with the concrete or sprinkled on the surface just prior to compacting. Uniformity of distribution is best obtained by the former procedure, which requires from ¾ to 1 lb. of non-slip aggregate for each square foot of finished surface. The aggregate is exposed by grinding. Non-slip concrete finishes are used particularly on stairways, in front of elevators, or on loading platforms. Non-slip surfaces are also highly desirable where floors are wet much of the time, such as in creameries and slaughter houses.

In offices, concrete floors may be covered with materials such as linoleum, rubber or cork tile. The structural concrete is finished to a smooth even surface slightly below finish grade. It is essential that the concrete be thoroughly dry before the covering is applied. Before laying the covering, place a patch of it on the floor and hold it down tight with a weight. If after 24 hours the concrete looks moist under the patch, it is not yet ready for laying the covering. When the concrete is finally dry enough, the covering may be laid without danger of "blistering".

Linoleum, rubber or cork tile coverings may be used also for tool rooms where dropping of hard brittle tools on an unyielding surface may cause too much breakage. In such places, a wood floor finish may also be used. Wood floors in factories are generally of the type in

Concrete floors are kept neat, clean, and sanitary in the Walgreen Company plant, Chicago. They require a minimum of cleaning and maintenance.

which wood is laid in a mastic binder on the top surface of the concrete floor.

Strong acid solutions may require a special acidproof covering such as asphalt blocks. The concrete base is troweled to a smooth surface and pitched to acid resistant drains. Premolded blocks may be used and pointed with acid resistant compounds, or acid resistant mixtures may be laid in place as one continuous sheet.

With ordinary care and strict adherence to specifications for the various types of concrete floors described in *Concrete Floor Finishes* the result is a smooth, impervious, hard and wear resistant surface which will not dust. Faulty construction procedures or use for which the floor was not intended when placed may combine to expose flaws here and there on the surface. Such flaws should be repaired just as soon as possible. It is poor economy to delay repairs because the steady pounding of truck wheels over a weak spot will gradually break down adjacent concrete which is in sound condition. The repair procedure is to chip away the damaged concrete to a depth of at least 1 in. and to put in a patch. The depth of the patch must be uniform, and no feathered edges should be permitted because they may break down rapidly. The hole must have vertical edges as illustrated in Fig. 16.

The patch must not be struck off flush with the top of the surrounding floor because then the patch will ultimately harden as a depressed area. The correct procedure is to run the strike-off board on shims laid on the old concrete around the patch, leaving the new concrete surface slightly above the old surface as illustrated in Fig. 17. After one to two hours, the patch is troweled down to its final grade, flush with the rest of the floor.

It is important that the patching concrete be as nearly as possible of the same mix as the original finish and that it be cured thoroughly as required for a heavy duty floor finish. Protection of the patch during curing may be insured by covering the area with a boiler plate with its convex side upward.

In addition to occasional patching, the only other maintenance, but an important one, is the cleaning of the floor surface. Accumulations of grit, nails, oil, dirt, molasses and sugar are detrimental to safety of the workers and may cause damage to the finish. Warm soapy water and stiff brushes will remove ordinary accumulations. After scrubbing, the floor should be mopped dry. Special cleaning methods for soiled floors are discussed in *Concrete Floor Finishes*.

In truck yards where a concrete slab is laid direct on the subsoil, a one-course construction is used. The construction is similar to that of highway concrete slabs, a rough broomed finish is used, and joints divide the slab into squares or rectangles.*

If the truck yard is over a basement or other occupied space, flat slab and two-way solid slab constructions are well suited for support of the loading. Design and detailing of joints are similar to corresponding features in bridges. The surface should be sloped to drain inlets and expansion joints should be installed as illustrated in Fig. 18.** Drainage gutters of sheet metal under expansion joints are recommended if leakage through joints will spoil contents stored below the yard floor. Downspouts should be exposed so that they can be cleaned out or replaced.

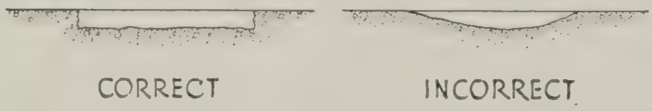

Fig. 16. Floor patch, correct and incorrect chipping.

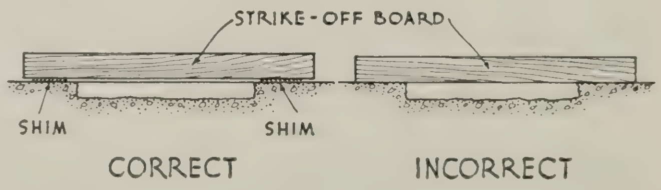

Fig. 17. Floor patch, correct and incorrect strike-off.

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*See booklet *Concrete Road Design*.

**Further description and additional details are given in booklet entitled *Concrete Bridge Details*.

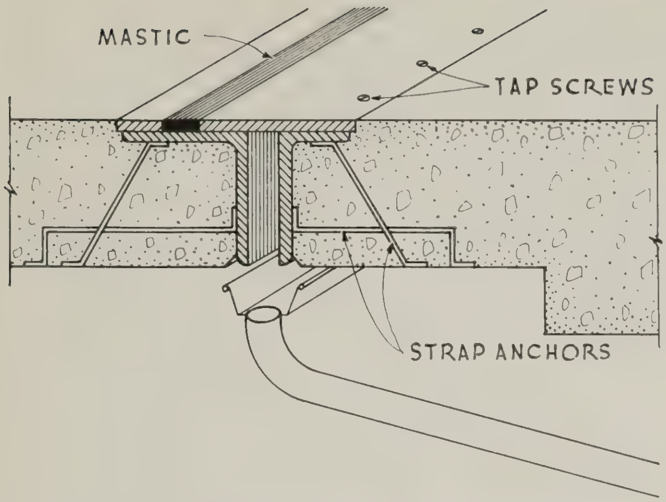

Fig. 18. Expansion joint detail for truck yards.

8. STAIRS

Study of fires in factories reveals that rather heavy loss of life is due to poor layout and inadequate maintenance of the exits combined with inferior construction. A fire or an explosion is apt to cause panic which in turn may lead to injury or death, especially at inadequate stairways and exits.

The problem of stairway design has been subject to thorough investigation the results of which, together with definite design standards, have been made available in print. For important sources of information reference is made to the U. S. Department of Commerce bulletin entitled *Design and Construction of Building Exits,** and to *Building Exits Code*, published by the National Fire Protection Association.**

Stairways are measured in units of 22-in. width, each of which accommodates one person. A width of two units, 44 in., is considered minimum for factory stairs although a sub-standard width of 36 in. is accepted for certain limited instances. A 44-in. or a 66-in. stairway should have handrails on both sides. For larger width, the addition of a center handrail is recommended. Handrails projecting not more than 3½ in. are not considered as encroaching upon the useful width but beams, columns and other obstructions are not permitted within the minimum widths.

The uninterrupted vertical height of a flight of stairs is limited to 12 ft. or, in some instances, even to 8 ft. Two flights with one intermediate landing is standard construction in factories. It is not permitted to use winders or to use flights having less than three steps each.

Fire doors at entrances to stairways must open toward the stairs. If doors can be folded back against the wall, they are not considered an obstruction in the stairway, but at any point of the swing the door must leave not less than 36 in. of the stairway unobstructed.

The usual rules for the dimensions of risers and treads, the latter being measured horizontally from nosing to nosing, are:

(1) Sum of one tread and two risers to be not less than 24 in. nor more than 25 in.;
(2) No riser to exceed 7¾ in.;
(3) No tread to be less than 9 in.†

Stairs designed accordingly have been found adequate, safe and practical. People are used to such steps and therefore can use them with the greatest degree of convenience.

There should be at least two 44-in. stairways in every factory building (except under certain sub-standard conditions), but more than two stairs may be required. Problems concerning number of stairways have been given exhaustive study, from which certain rules have been developed.

One rule concerns the distance any occupant on a floor has to travel to reach a stairway. One hundred feet is generally considered maximum length of travel in buildings in the classification known as "high hazard occupancy".‡ The distance permitted is 150 ft. in buildings that are equipped with sprinklers and built of fire resistant construction.

Other rules concern the time in which the building can be evacuated, counting 45 persons per unit width in one minute walking down the stairs. Or the basis for calculating the number of stair units may be the requirement that all occupants should be able to find refuge on the stairs, one person being assumed to occupy every other tread with a corresponding number of persons on the landings.

One simple rule has been formulated as follows: Units of exit width shall be provided for each story above the first by dividing gross area of floor in one story (in square feet) by 6,000 for low or medium hazard occupancy or by 3,000 for high hazard occupancy·

Non-enclosed stairs of the type known as fire escapes are not to be counted as regular stairways. The enclosed fire escapes or smokeproof stair towers used in certain territories differ from interior stairs mainly in that glazing is omitted in the window apertures. Smokeproof stair towers as well as interior stairs should be protected against infiltration of smoke by means of a vestibule at the entrance to the stairs. The vestibule must be isolated by self-closing fire doors and must not open directly on the stair treads but should open on a landing. Doors must swing in the direction of travel to the outside.

If the stairs do not open direct to the outside at ground level, a protected passageway must be provided

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*Available from Superintendent of Documents, Washington, D. C. Cost: 10c.

**Address: 60 Batterymarch Street, Boston, Mass. Cost: 75c.

†Other rules in use are: sum of riser and tread to be 17½ to 18 in.; product of riser and tread to be 70 to 75.

‡For definition of occupancy rated as "high, medium, and low hazard", see *Building Exits Code* referred to in this section.

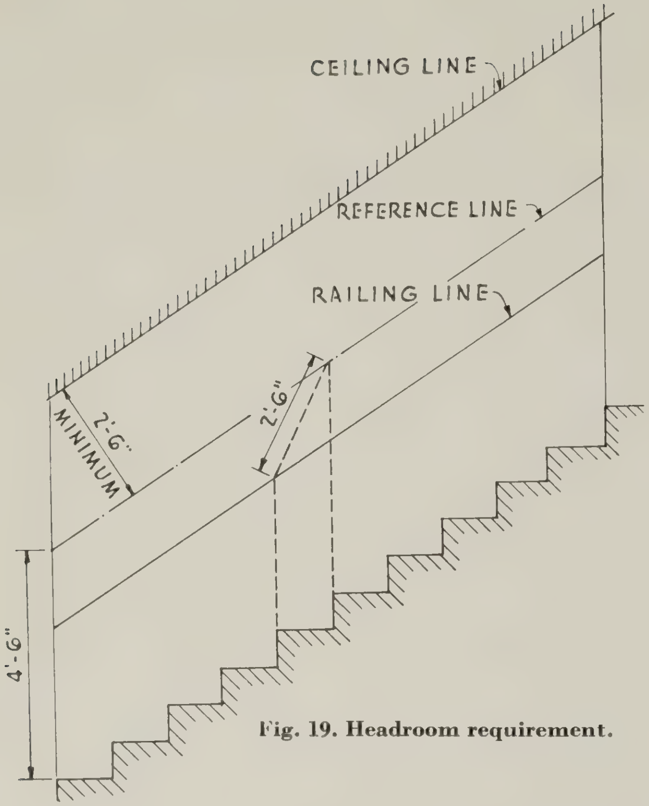

Fig. 19. Headroom requirement.

for connection to outside.

Boiler rooms and other rooms below street level must have two exits, one of which may be a ladder leading direct to the street.

The question of enclosure for stairways is an important one. There should be no openings in the enclosure except those needed for access and light. The enclosing walls as well as the stair structure itself should be of incombustible material and should have at least a 2-hour fire rating. The U. S. Department of Commerce bulletin on *Fire Resistance Requirements** gives a 2-hour rating to walls of (1) 4-in. concrete block, plastered on both sides**, and to (2) 4-in. solid concrete with not less than 0.2 per cent reinforcement in each direction. When plastered on both sides, a 3-in. thickness of concrete is sufficient.

For the determination of headroom required in stairways, the procedure illustrated in Fig. 19 is quite commonly used. Mark a reference line parallel with the steps at a height measured vertically 4 ft. 6 in. above the line through the stair nosings. A clearance of 2 ft. 6 in. as shown with respect to the reference line is considered the minimum allowed. Determination of the height at which the railing is to be attached is also illustrated in Fig. 19.

The framing in a floor slab for a stair opening may be made in accordance with the types of framing which are illustrated for openings in Figs. 10 and 11. Fig. 20 shows a typical vertical section through a stairway suitable for an industrial building. The inclined concrete stair slab is designed as a one-way slab supported on and cast integrally with beams as shown. The landing construction may be suspended by hangers from the floor above, supported on concrete struts from the floor below, or may bear on the enclosing walls. A live load of 100 p.s.f. is satisfactory for stair design. Reinforcing bars extending from the inclined slab into the landing slabs should not be bent at re-entrant angles but should be lapped as indicated.

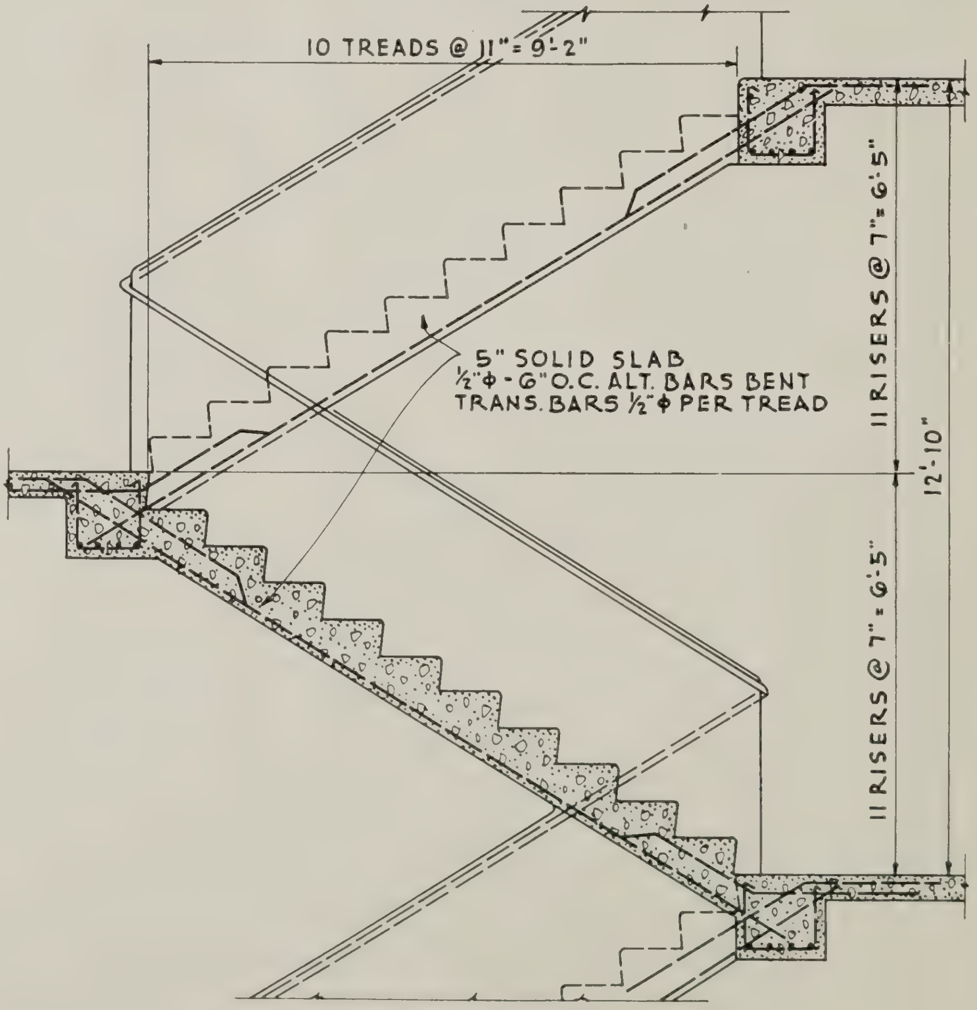

Fig. 20. Vertical section through concrete stairs.

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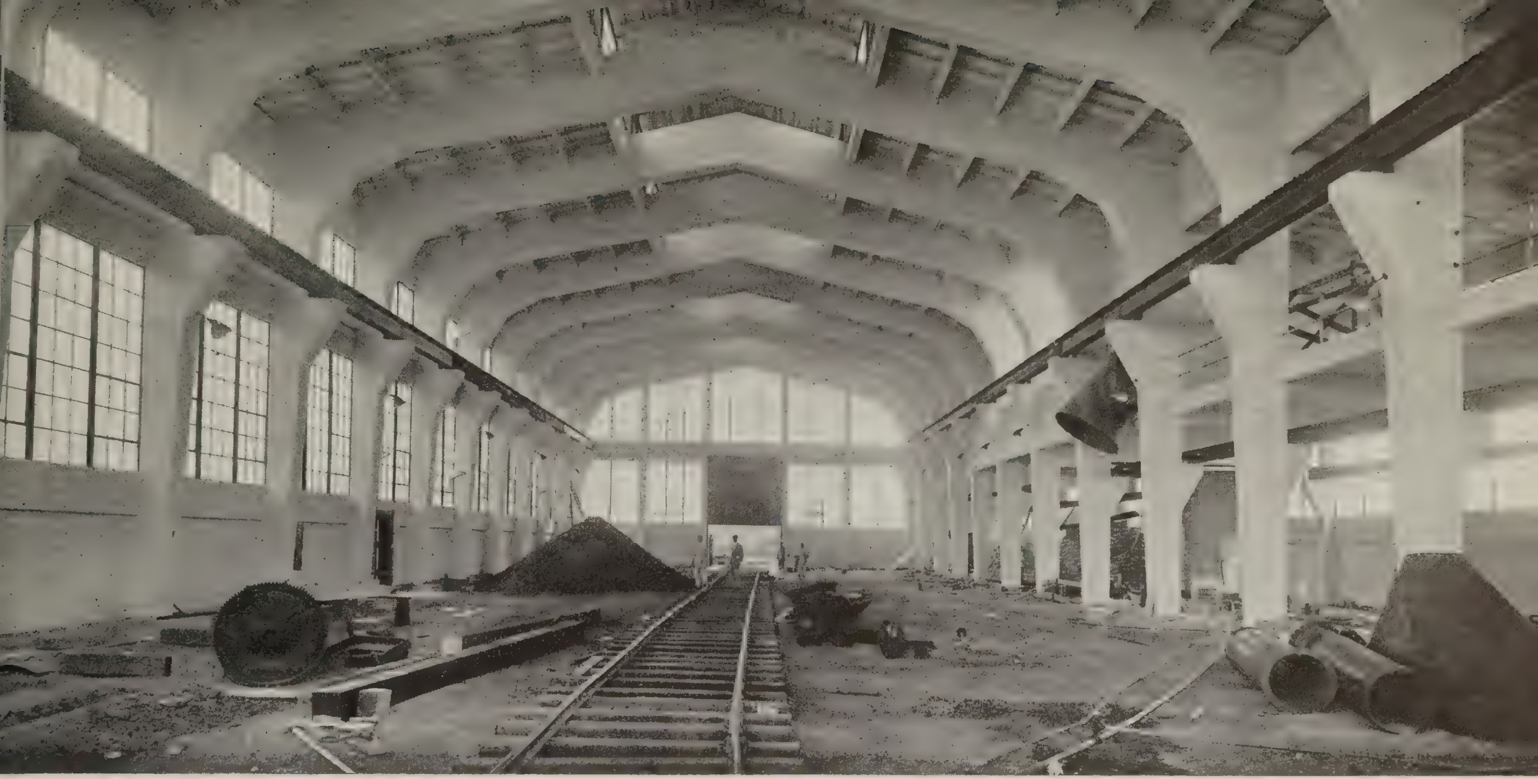
*See reference in Section 11.

**The block thickness and requirements for plaster depend upon the type of aggregate used and the face shell thickness. Further information is given in *Concrete Information ST-47, Fire Resistance Ratings of Building Materials.*



Foundry building at Garfield, Utah, has rigid frame concrete roof with 70-ft. span. Mezzanine construction and crane rail brackets are cast integrally with columns. Ample daylight is provided through tall windows and monitors. Designed and constructed by Villadsen Bros., Inc.

Two types of stair slab finishes are illustrated in Figs. 21 and 22. In both of them, the structural stair slab is cast first as outlined. Later on, the finish is applied either as a regular two-course construction, see Fig. 21, or the finish may be of precast units as in Fig. 22. Both types give excellent service and are often built with a non-slip surface.

It is good practice to place stairways in separate tower structures adjacent to the factory building. In addition, such towers are sometimes used to house elevators and utilities including risers for electricity, steam, water and compressed air. The top of the tower accommodates elevator machinery and water tank. The use of utility towers has the advantage that the entire width and length of the floors are left unobstructed.

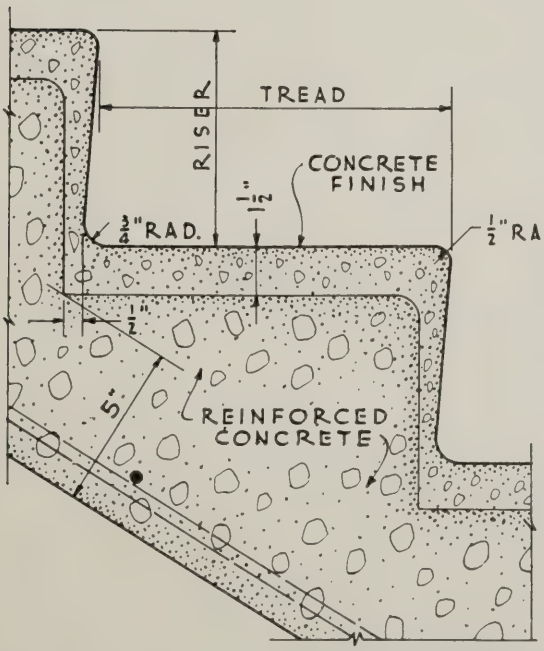


Fig. 21. Two-course cast-in-place concrete finish on stairs.

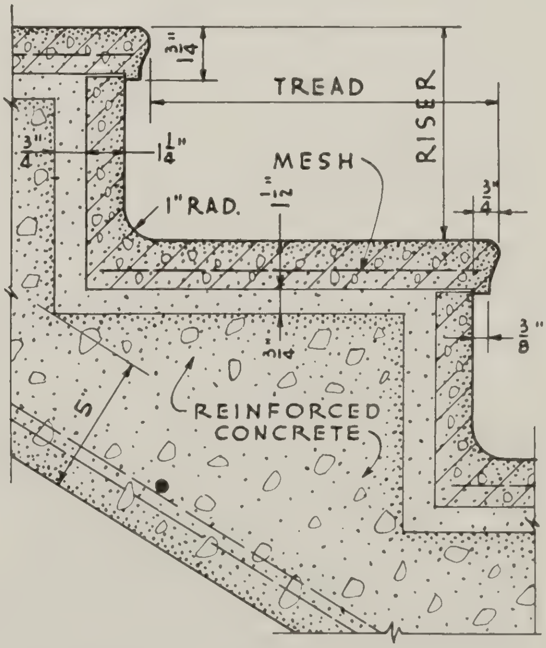


Fig. 22. Precast concrete finish on stairs.

9. WALLS

A characteristic feature in factory walls is that piers between windows are reduced to the least possible number and width. As a rule, the pier width is made not greater than the width required for the support of loads, and the main function of the pier is therefore a structural one. Since factory design architecturally may be said to be "functional", the tendency is naturally to expose the structural material in the wall. Concrete is both a structural and an architectural medium, and this double function makes concrete particularly well suited for wall construction in factories.

"Architectural concrete" exposed in the walls differs from "structural concrete" mainly in that special care must be taken to make forms for architectural concrete substantial, true and tight. They must also be so designed that they can be stripped without danger of damaging corners and lines. Various designs involving recesses and offsets may be used, and many attractive textures and details may be obtained by judicious use of form lumber, linings and waste molds.*

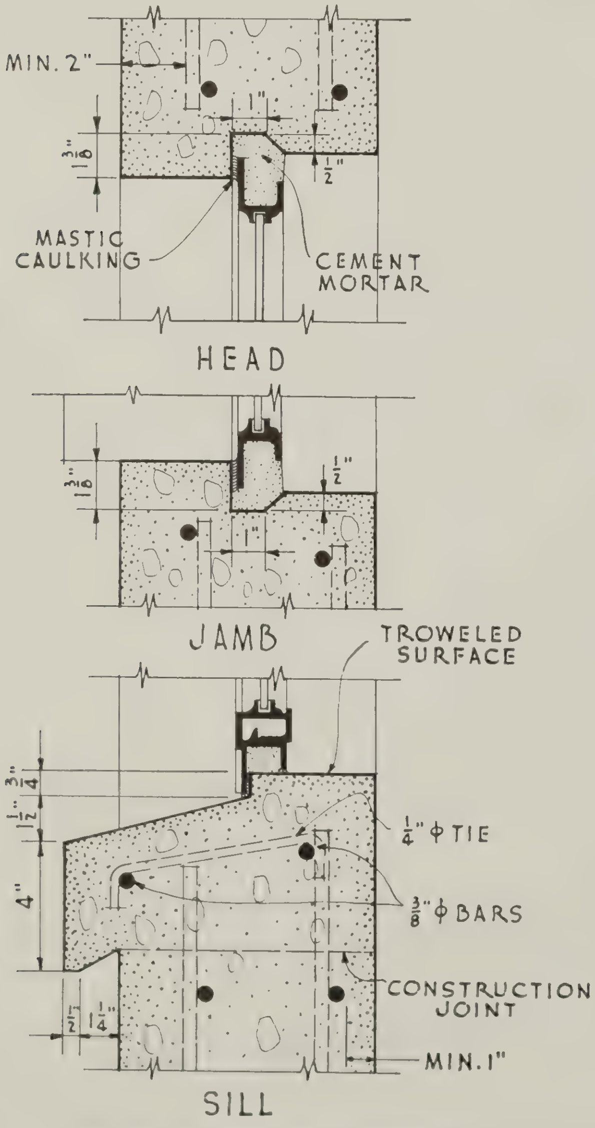


Fig. 23. Steel sash set in concrete wall.

Windows in factories are generally of steel sash, and the best practice is to set them after the forms have been stripped. Fig. 23 shows details of steel sash set in a concrete wall. It illustrates how rabbets and reveals are provided to receive the window frame. The window sill in Fig. 23 is of the projecting type, but window sills may also be made flush with the spandrel.** Special attention should be given to setting the window frame so that it is perfectly tight, but no part of the window frame should be embedded in the wall concrete because corrosion of the steel may then damage the surrounding concrete.

Spandrels serve as structural members and also as important elements in the architectural design. Both requirements are fulfilled with architectural concrete construction. Spandrels may extend both above the floor and below the ceiling, but in best factory design spandrels do not project below the ceiling. If the structural requirements of a spandrel can be met with a depth equal to the depth of the floor itself, a construction joint may be placed at floor level. This simplifies the construction of forms and the placing of concrete. If necessary, the construction joint may be concealed by means of a groove, an offset or other architectural detail.

It may be necessary to include in the spandrel beam the entire depth from window head below to window sill above. An upturned spandrel should usually be concreted in one continuous operation simultaneous with the adjacent floor. In this case, construction joints are placed at window heads and at window sills.†

Expansion joints may be used in long buildings and must be used where a new building unit is attached to one previously constructed. Observations indicate that buildings of architectural concrete seldom need expansion joints, unless they are more than 200 ft. long. Additional joints may be necessary in buildings with wings, offsets or other irregular shape.

The function of expansion joints in factory buildings generally is to allow for shrinkage and temperature change. In warm weather construction, the space in the joint should be not more than ½ in., but a somewhat larger space may be needed in cold weather construction. The clear distance of 1 in. shown in Fig. 24 is assumed to represent the joint at its widest position. The flexible copper strip near the exposed face of the wall keeps out water and air. One detail in Fig. 24

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*Important details are described in booklet *Forms for Architectural Concrete* and in *Concrete Information AC-11, Textures.*

**Details for both types are given in *Concrete Information AC-6, Windows,* which contains numerous details for forms, plastered walls, wood sash, reinforcement and cased openings.

†Details for several types of spandrel forms and for reinforcement are presented in *Concrete Information AC-9, Spandrels.* Architectural concrete walls embrace many other details besides those discussed. For sketches, photographs and description of such details, reference is made to Concrete Information Sheets AC-7, *Doorways;* AC-8, *Reveals;* AC-10, *Pilasters;* AC-14, *Ornament;* and AC-21, *Canopies.*

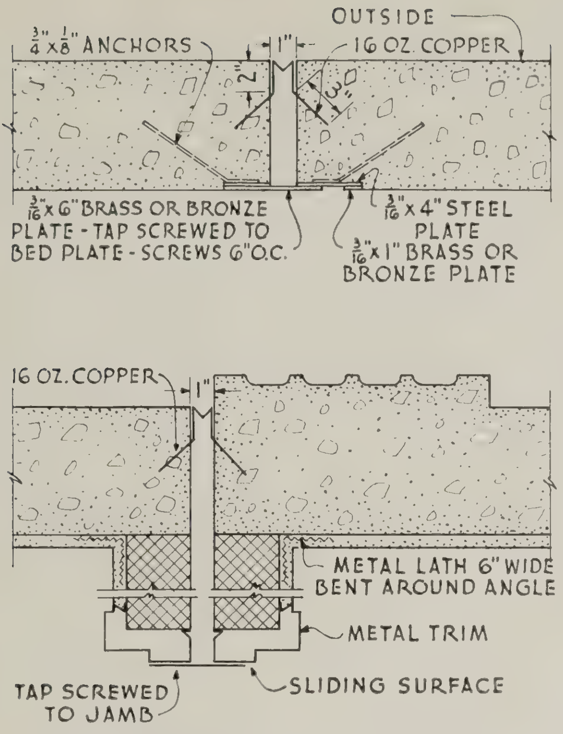
OUTSIDE
3/4" x 1/8" ANCHORS
1"
16 OZ. COPPER
2"
3"
3/16" x 6" BRASS OR BRONZE PLATE - TAP SCREWED TO BED PLATE - SCREWS 6" O.C.
3/16" x 4" STEEL PLATE
3/16" x 1" BRASS OR BRONZE PLATE
16 OZ. COPPER
1"
METAL LATH 6" WIDE BENT AROUND ANGLE
METAL TRIM
SLIDING SURFACE
TAP SCREWED TO JAMB

Fig. 24. Expansion joints for concrete walls.

shows a joint in a wall without offset. The joint in the other detail is partly concealed by means of an offset. The detail showing a partition at the joint is suitable where a new unit is added to a present building, but otherwise it is better to avoid having partitions at joints. Expansion joints should be carried through basement walls and, of course, also through parapets.*

Thermal insulation of walls is not, as a rule, required in factories. In air conditioned plants, however, the concrete walls may have to be insulated, and insulation becomes a necessity in cold storage warehouses. Fig. 25 illustrates two stages of the construction of a wall that is to be furred with insulation board. Galvanized wire loops are indicated as the means of attaching furring strips to the wall.**

Reinforcement in architectural concrete walls should be designed and detailed to resist stresses created by gravity and exterior forces. In addition, adequate reinforcement must be provided for stresses caused by volume changes in accordance with the recommendations in the table in this section. Note that all bars in the table are 3/8 in. round, with spacings from 6 to 12 in. Larger bars with greater spacings are less effective in preventing cracking. Additional bars are placed at openings as illustrated in Fig. 26. Vertical bars in spandrels should preferably be detailed as U-stirrups. The arrangement of typical wall reinforcement is shown

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*Full description of various joint details in walls, floors and roofs is given in *Concrete Information AC-12, Expansion Joints in Concrete Buildings.*

**Other means of attachment are shown in detail together with a discussion of thermal insulation in *Concrete Information AC-16, Furring for Architectural Concrete Walls.*

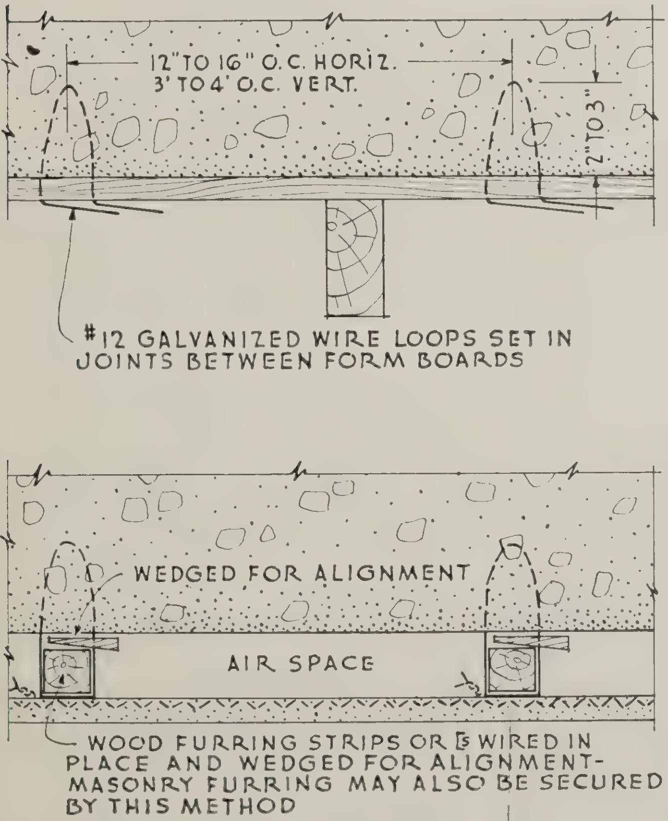
12" TO 16" O.C. HORIZ.
3' TO 4' O.C. VERT.
2" TO 3"
#12 GALVANIZED WIRE LOOPS SET IN JOINTS BETWEEN FORM BOARDS
WEDGED FOR ALIGNMENT
AIR SPACE
WOOD FURRING STRIPS OR ⊏ WIRED IN PLACE AND WEDGED FOR ALIGNMENT - MASONRY FURRING MAY ALSO BE SECURED BY THIS METHOD

Fig. 25. Furring for architectural concrete walls.

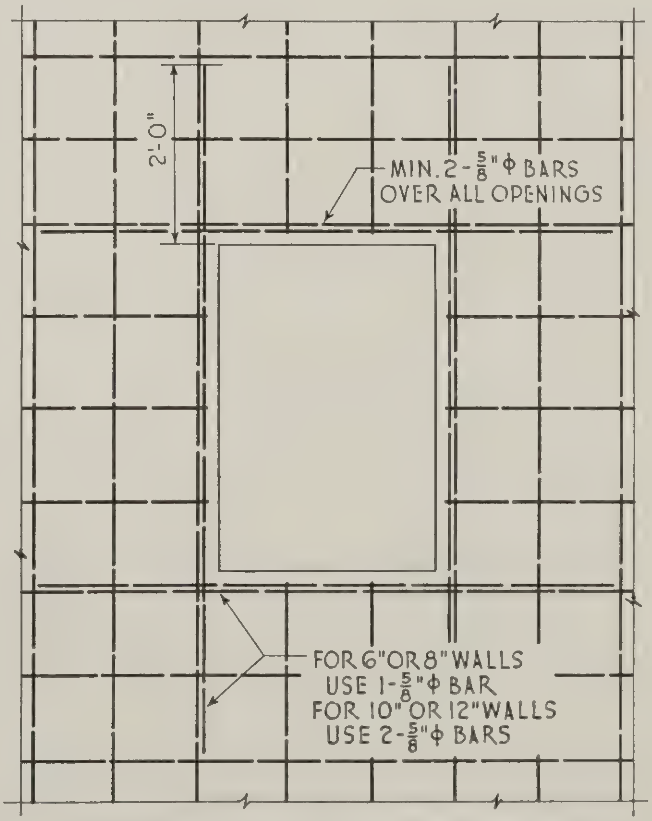
2'-0"
MIN. 2-5/8" ϕ BARS OVER ALL OPENINGS
FOR 6" OR 8" WALLS USE 1-5/8" ϕ BAR
FOR 10" OR 12" WALLS USE 2-5/8" ϕ BARS

Fig. 26. Reinforcement around wall openings.

Spinning mill at Bridgeport, Pennsylvania, designed by The Ballinger Company, has flat slab floor cantilevered beyond the exterior columns, and windows are made continuous around the building. Lighting is further improved by giving concrete surfaces a coat of white semi-gloss paint. Note the pipe holes for future use at each column head and the inserts in ceiling for suspension of pipes.

in Fig. 27. There is only one curtain of bars in the 6 and 8-in. walls, but two curtains in thicker walls. In the outside curtain, the vertical bars are placed at a clear distance of 2 in. from the outside face, and the horizontal bars are tied to the inside of the vertical bars. This arrangement permits puddling concrete between the outside forms and the reinforcement and leaves ample room to use an elephant trunk or spout for placing concrete. Bar splices should have a 30-diameter lap for 3,000-lb. concrete and a 40-diameter lap for 2,500-lb. concrete.*

Means of moving boilers and other large equipment in and out of the building should be considered and suitable openings provided in both floors and walls. Window openings are usually sufficiently large for this purpose, but if not, they may be enlarged by means of removable concrete panels.

WALL REINFORCEMENT

Wall Thickness Inches	Horizontal Reinforcement	Vertical Reinforcement
6	⅜-in. round at 8-in. centers in outside face of wall.	⅜-in. round at 8-in. centers in outside face of wall.
8	⅜-in. round at 6-in. centers in outside face of wall.	⅜-in. round at 8-in. centers in outside face of wall.
10	⅜-in. round at 10-in. centers in both faces of wall.	⅜-in. round at 12-in. centers in both faces of wall.
12	⅜-in. round at 8-in. centers in both faces of wall.	⅜-in. round at 12-in. centers in both faces of wall.

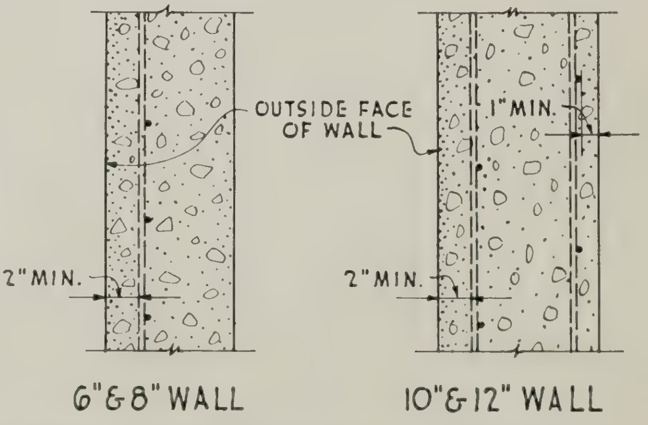

Fig. 27. Location of reinforcement in concrete walls.

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*For further details and discussion, reference is made to *Concrete Information AC-17, Reinforcing for Architectural Concrete Walls.*

10. ROOFS

The superimposed loads on roofs required in various codes vary from 25 to 50 p.s.f., and to this load must be added from 5 to 8 p.s.f. for ordinary roofing, plus 5 p.s.f. for insulation board, if required.

No slope need be provided for drainage of flat roofs; in fact, it is preferable to make them absolutely level. Drains and overflows are frequently placed at least 2 in. above roof level. As a result, a sheet of water covers the roof practically all the time. This helps to preserve the roofing and also by slow evaporation assists materially in cooling the story below the roof.

At all vertical surfaces roofing should be flashed and counter flashed as illustrated in Fig. 28. When the parapet is cast, a raggle is provided as shown, and the flashing is later calked securely in this groove. The height from roof to raggle depends upon climate and precipitation. A detail similar to that in Fig. 28 is used around openings for skylights.*

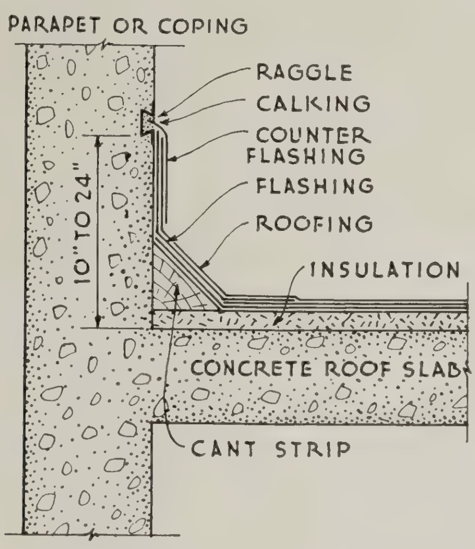

Fig. 28. Roofing and flashing at parapet.

In places where parapets are not required, the roofing and flashing detail in Fig. 29 may be used. A continuous wood blocking is set in and fastened to the concrete when it is cast, and both flashing and gutter are later attached to the blocking.

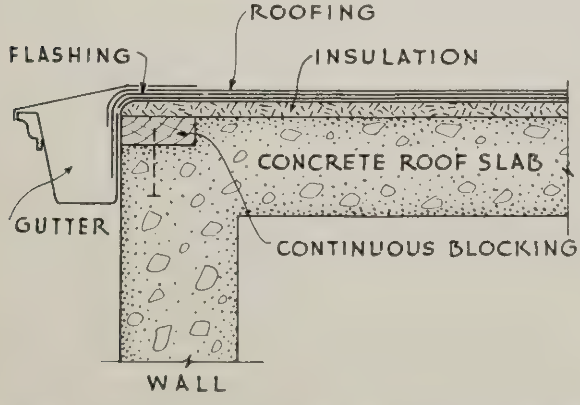

Fig. 29. Flashing and gutter for roof without parapet.

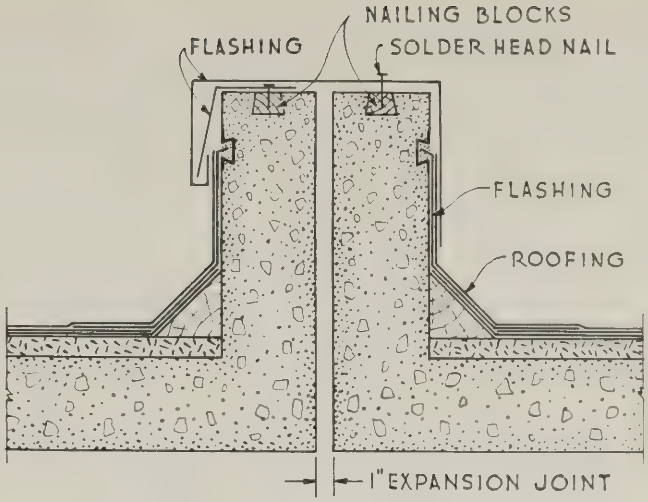

Fig. 30. Expansion joint in roof.

Expansion joints in roofs may be constructed as shown in Fig. 30. It is essential that the joints be both watertight and flexible. On either side of the joint a parapet is built which is similar to that illustrated in Fig. 28. The tops of the two parapets are covered with a flashing which is nailed to a block on one side of the joint but not fastened to the other side.**

For both flat and pitched roofs, a concrete joist floor design is suitable. If the supporting structure is of concrete, it is cast integrally with the decking. If steel roof trusses are used, all forms for the decking may be attached to and supported by the roof structure.

A type of roof deck frequently used consists of concrete made with stone, gravel, slag or special lightweight aggregates, which is cast on metal lath or on wire mesh with paper backup. The lath or mesh is supported and stretched on purlins. This type of slab when covered with insulation and roofing gives excellent service at low cost. The lath provides a good ground for plastering, or the bottom of the roof construction may be concealed and protected against fire by a suspended ceiling consisting of cement plaster on metal lath supported by pencil rods hanging from the roof.

Insulated roof decks may be constructed by placing the concrete on cork slabs, the contact surfaces of which are so prepared that they bond with the bottom of the concrete slab without mechanical aid, although wire loops are sometimes hooked into the cork to insure positive anchorage. Such cork slabs serve simultaneously as the form for the concrete, as insulation, and as acoustic lining for the ceiling. Other properly prepared insulating boards may be used in lieu of cork.

For long-span roofs, several types of rigid frames of reinforced concrete and also reinforced concrete shell structures are available. The top member of the rigid frame may be straight from parapet to parapet, or it

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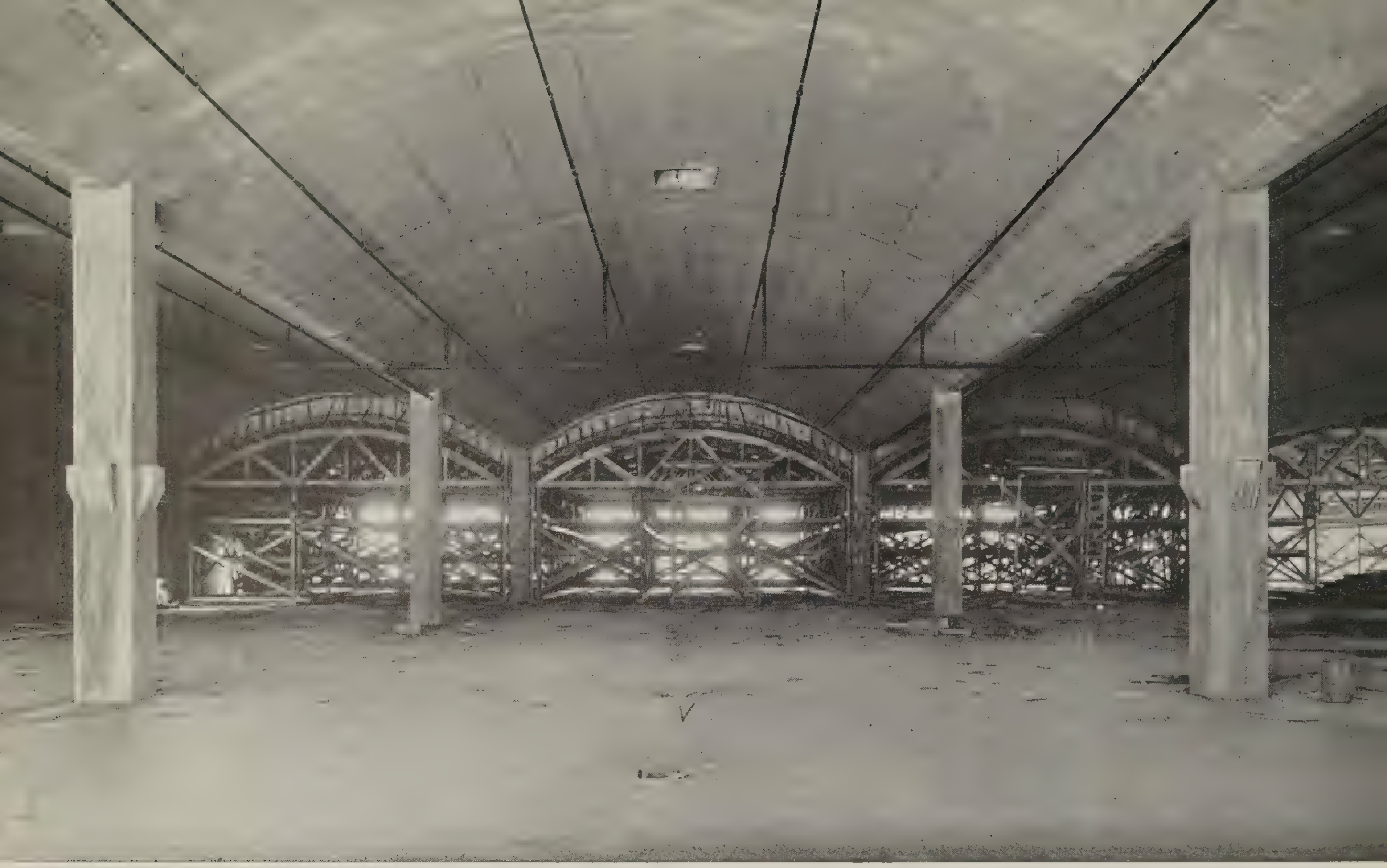
*Copings for architectural concrete walls may be either precast or cast-in-place. Both details, together with reinforcement and forms, are illustrated in *Concrete Information AC-5, Copings and Parapets.*

**Another detail and full description are given in *Concrete Information AC-12, Expansion Joints in Concrete Buildings.*



Barrel shell roof of reinforced concrete with average shell thickness of 3½ in. used in factory building with 188,000 sq.ft. of usable floor area occupied by Armstrong Tire and Rubber Company, Natchez, Miss. This building, which is of concrete throughout, has the lowest possible cost of maintenance and fire insurance. The bays are 40 ft. wide and the typical longitudinal spacing of columns is 50 ft. Designed by Roberts and Schaefer Co., Chicago.

may be pitched as shown in Fig. 31.* Rigid frames of similar shape may be built continuous over two or more spans. The decking or roof slab spanning from frame to frame may be either a solid slab on concrete beams, or a ribbed slab may be used.

There are two basic types of reinforced concrete

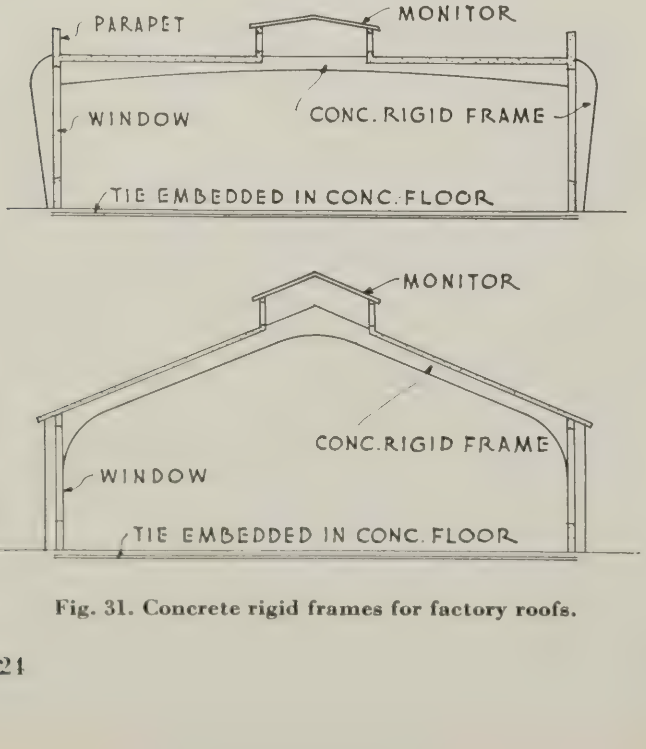


Fig. 31. Concrete rigid frames for factory roofs.

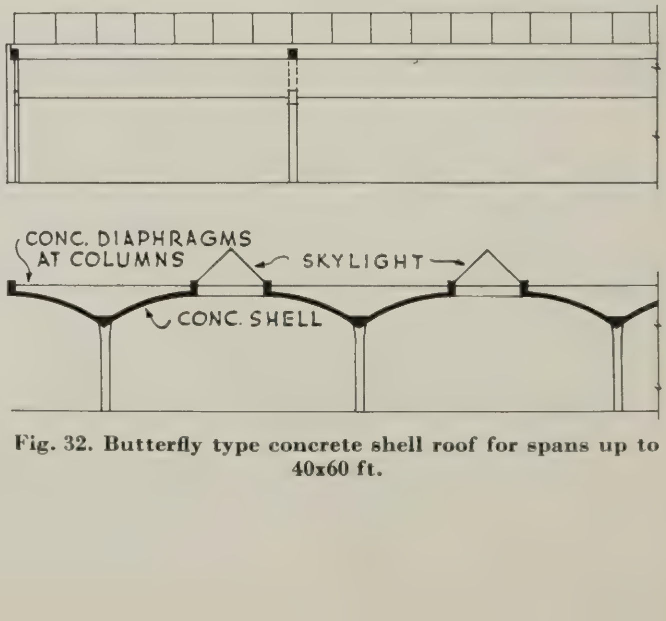


Fig. 32. Butterfly type concrete shell roof for spans up to 40x60 ft.

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*The analysis of building frames of the types in Fig. 31 is illustrated by many numerical problems presented in *Concrete Information ST-42, One-Story Concrete Frames Analyzed by Moment Distribution*, and *ST-43, Gabled Concrete Roofs Analyzed by Moment Distribution.*

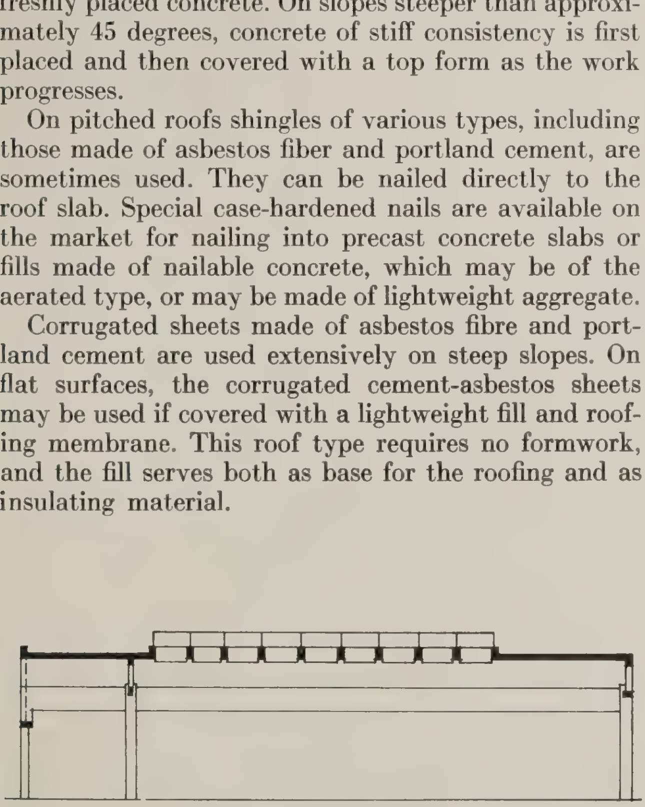
shell roofs* especially adapted to industrial buildings. They are: (1) the butterfly type for spans up to 40x 60 ft. (see Fig. 32); and (2) the barrel shell type for spans up to 60x200 ft. (see Fig. 33). In such roofs the shell, which usually has a thickness of 3 or 3½ in., is stiffened by edge members and diaphragms. The curved and stiffened shells have ample strength to carry any loads to which they are subjected, including unbalanced wind and snow loads, with a large factor of safety in spite of the very long spans for which they are used.

The total absence of interior columns in many cases and the wide spacing of columns where they are required at all is a distinct advantage of shell roof construction for industrial plants. In buildings that are too wide to be illuminated adequately from side-wall sash, skylights can be provided in either the barrel shell or butterfly type roofs, so a good distribution of light may be had in even the widest buildings.

Concrete used on the slope of a pitched roof or on the steeply pitched portion of a shell roof should be placed fairly stiff. If the correct consistency is used, top forms are not needed for slopes less than approximately 45 degress. The concrete finishers may do their work from scaffolds supported by wooden shoes on the freshly placed concrete. On slopes steeper than approximately 45 degrees, concrete of stiff consistency is first placed and then covered with a top form as the work progresses.

On pitched roofs shingles of various types, including those made of asbestos fiber and portland cement, are sometimes used. They can be nailed directly to the roof slab. Special case-hardened nails are available on the market for nailing into precast concrete slabs or fills made of nailable concrete, which may be of the aerated type, or may be made of lightweight aggregate.

Corrugated sheets made of asbestos fibre and portland cement are used extensively on steep slopes. On flat surfaces, the corrugated cement-asbestos sheets may be used if covered with a lightweight fill and roofing membrane. This roof type requires no formwork, and the fill serves both as base for the roofing and as insulating material.



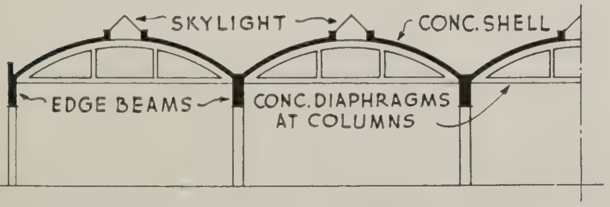
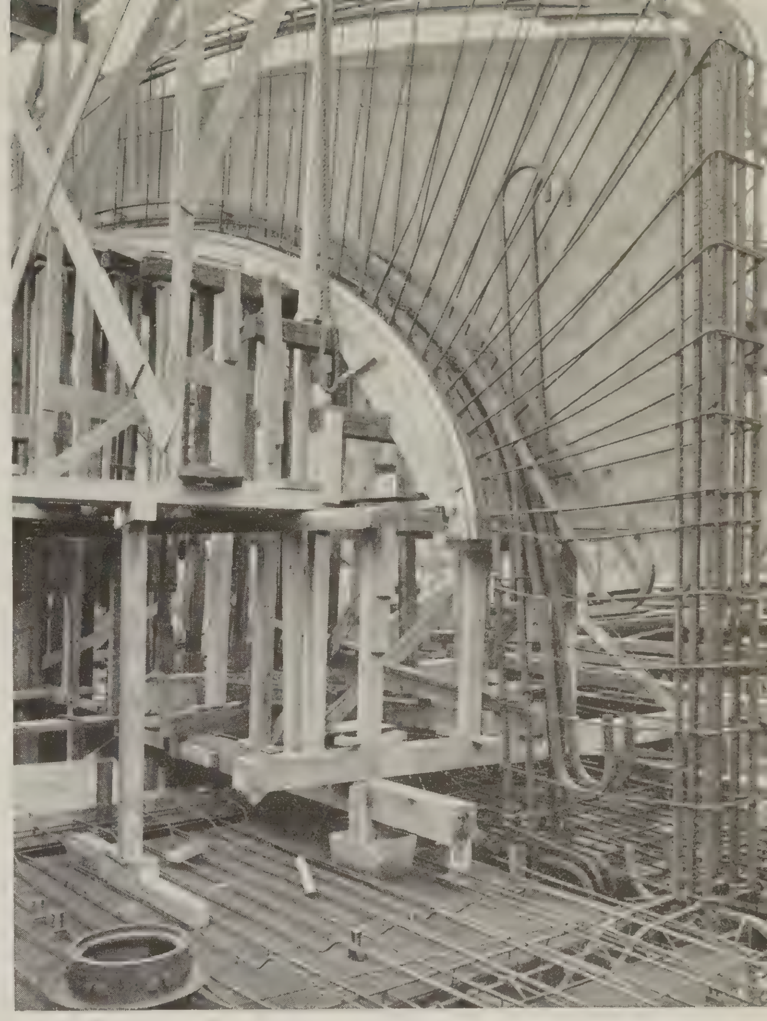


Fig. 33. Barrel type concrete shell roof for spans up to 60x200 ft



Construction view of concrete roof structure of Armour and Company beef house. Attention is called to the arrangement and placing of reinforcement, to formwork details, to inserts and collars for openings in floors.

Various types of precast concrete construction have been used for roofs. They require little or no formwork, are economical for supporting relatively light superimposed load, and are easy to handle and place.

The precast concrete joists illustrated in Fig. 34 are available with over-all depths of 8, 10, and 12 in., and may be used on spans up to 24 ft. The joists are set on the supports, and wood forms attached to them for a concrete topping slab, 2 or 2½ in. thick. The joists extend ½ in. into the cast-in-place slab and are doweled to it. Insulation board, if any, and roofing membrane

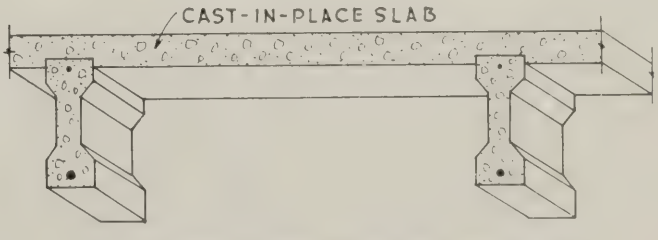


Fig. 34. Precast concrete joist roof construction.

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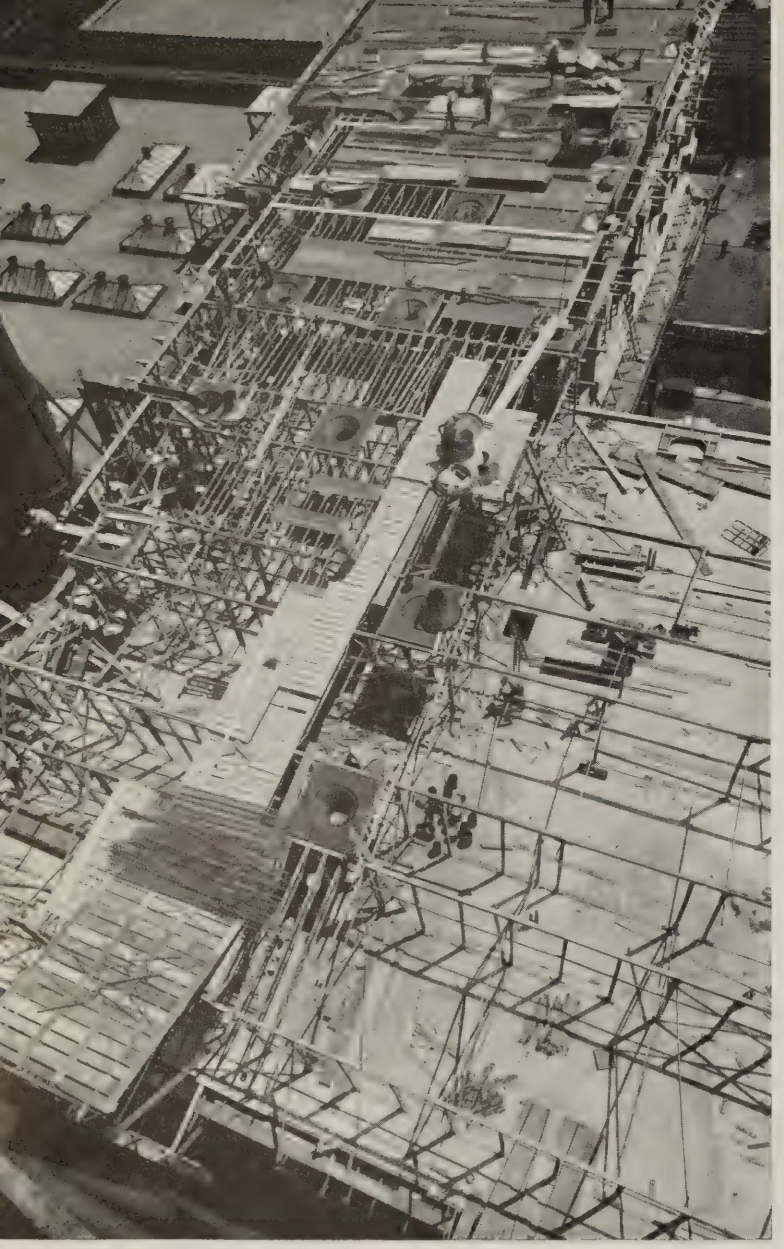
*See "Principles of Concrete Shell Dome Design," by Eric C. Molke and J. E. Kalinka, *Journal of the American Concrete Institute*, May-June, 1938.



Construction view of addition to A. B. Dick Building, Chicago, designed by Nimmons, Carr and Wright, architects, illustrates numerous steps in connection with the simple erection of forms for flat slab. The first step is shown in the lower portion and the last step in the upper portion of the photograph. Built by B-W Construction Company.

are placed on top of the slab.*

"Cement tile" of various types are used frequently on roofs and give an excellent, economical construction. In general, the tile are 2 ft. wide and are laid on purlins spaced up to 8 ft. apart. Some tile are flat on both top and bottom, but others, called channel tile, consist of a slab with thickened edges on the two longer sides. Lightweight concrete is generally used to facilitate handling, and numerous special shapes are manufactured for connections, eaves, ridges, valleys, and for other special requirements. A nailing concrete is sometimes cast integrally on top of the tile for fastening of ornamental roofings, but ordinary membrane roofing laid in mastic directly on top of tile requires no nailing.

11. FIRE RESISTANCE REQUIREMENTS

Standards have been adopted by which fire resistance qualities of types of construction are specified and evaluated. It is not sufficient merely to distinguish between "fireproof" and "non-fireproof" construction. The designer now describes a structure or a part thereof by saying that it has a fire resistance of a certain duration, or differently expressed, that it can withstand exposure to fire for a certain number of hours.

The Building Code Committee of the Department of Commerce in 1931 made a report entitled *Recommended Minimum Requirements for Fire Resistance in Buildings.*** The committee specified the fire resistance required for important structural parts in buildings of various types of construction. Some of the committee's requirements given in terms of hours are listed in the table below. The committee also established fire resistance ratings in hours for various structural parts.

The two types of construction included in the table do not have equal fire resistance. Type 1, described as "fully protected", has a fire resistance which is superior to that of Type 2, called "protected" construction. Type 2 may cost less to build but it is subject to higher insurance rates and more stringent restrictions are applied to its use than to Type 1.

FIRE RESISTANCE REQUIREMENTS IN HOURS

Structural Part	Type of Construction[1] 1. Fully Protected	 2. Protected
Walls—Fire	4	4
Party	4	4
Bearing	4	3
Others	2½	2
Piers	4	3
Columns—Supporting walls	4	3
Others	4	2
Girders—Supporting walls	4	3
Others	2½	2
Trusses—Supporting walls	4	3
Others	4	1½
Beams	2½	1½
Floors	2½	1½
Roofs	2½	1½

[1]For other types, see *Recommended Minimum Requirements for Fire Resistance in Buildings.*

The use of the table may be illustrated by considering a simple example. In fully protected construction all columns shall have a fire resistance of 4 hours. The designer may use any one of several available types of columns, provided they have a 4-hour rating.

The committee report also includes ratings for various structural parts with numerous types of fire pro-

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*Numerous details and loading tables are presented in the booklet *Precast Joist Concrete Floors.*

**Available from Superintendent of Documents, Washington, D. C. Cost: 10c. This report is being used as the basis for fire resistance ordinances in numerous municipalities.

tection.[*] The 4-hour rating required for columns is satisfied by use of "Reinforced concrete, coarse aggregate 'A',[**] 1½-in. concrete protection outside the bars". The 2½-hr. rating required for beams is satisfied by use of "Reinforced concrete, any type of coarse aggregate, 1½-in. concrete protection". The 2½-hr. rating for floors and roofs is satisfied by use of several types of construction, one of which is "Reinforced concrete solid slab, minimum thickness of 4½ in., ¾-in. concrete protection below bars". The 4-hr. rating required for walls is satisfied by use of "Reinforced concrete, 6-in. minimum thickness, 0.2 per cent reinforcement in each direction".

The fully protected type of construction discussed is, from the standpoint of fire, not restricted in respect to occupancy, height of building, or size of floor area. Certain restrictions are applied, however, to other inferior types of construction. The "protected" type of construction, for example, is limited to a building height of 50 ft. for garages and 80 ft. for factories and warehouses. The total floor area is limited to 25,000 sq. ft.

The purpose of providing fire resistance in floors and walls would be defeated if vertical shafts for stairways, elevators and other purposes were not given proper attention. Recommendations for shaft enclosures and for protection of openings in walls are included in the committee's report which requires shaft enclosures having a 2-hour rating and approved doors.

Fire laws and ordinances for congested areas favor or even demand the best type of fire resistant construction because a fire hazard in any building is a constant threat to adjacent property. On the other hand, less fire resistant construction is often permitted in outlying or suburban areas where there is less congestion. Higher insurance premiums on such construction and possible business loss due to shut-down in case of fire will often offset any saving in first cost and make the use of the best type of fire resistant construction advisable.

12. DESIGN FOR ADDITIONAL STORIES

It is good practice to *plan* a building in its final expanded shape even if it is intended to *build* that portion only which is required for present needs. In doing this, the designer will invariably give thought to various details which might otherwise be overlooked.

Provision should be made in the original design for adding new stories to the building by making footings and columns of sufficient size to carry future loads. If this is done, no structural change is involved when expansion becomes necessary.

The case may come up in which it is desired to add more floors than originally planned, a case which may be handled in one of several ways. It is possible that some of the floors will not be loaded as heavily as assumed in the original design. Lower load limits may then be established and advantage can be taken of the load reduction. It is also possible that changes have been made in the building code which permit an increased load on columns already built.

In most cases, however, it will become necessary to consider the use of dead loads for new construction which are smaller than those anticipated in the original design. This may be done by choosing the type of concrete floor design which requires the least volume of concrete, by specifying a lightweight concrete, or by a combination of both.

The concrete joist floor system with removable metal pans is one of the lightest types suitable for manufacturing buildings. In the one-way concrete joist floor, the metal pans are generally 20 or 30 in. wide separated by joists not less than 5 in. wide. The pans may have tapered ends in order to provide for shear and compression stresses at supports. The general layout of a concrete joist floor is illustrated for garages in Section 22. In factory floors, a bridging joist, say 5 in. wide, should be added at midspan running perpendicular to the main joists in order to help distribute heavy concentrated loads.

Lightweight concrete may be designed with a weight of approximately 100 lb. per cu. ft. Its use will account for a reduction of approximately one-third in the dead load as compared with ordinary stone or gravel concrete. Several types of lightweight concrete aggregates are available.[†]

An important point in connection with design of tall buildings is the reductions allowed in live loads used for design of columns and footings. A building code committee appointed by the U. S. Department of Commerce submitted in 1924 a report on "Minimum Live Loads Allowable for Use in Design of Buildings".[‡] The committee reported on "Reductions in Live Loads" as follows: "Except in buildings for storage purposes, the following reductions . . . are permissible in designing all columns, piers or walls, foundations, trusses and girders.

"Reduction of *total* live loads carried:

Member Carrying	**Per Cent Reduction**	**Member Carrying**	**Per Cent Reduction**
one floor.......	0	five floors......	40
two floors......	10	six floors......	45
three floors....	20	seven or more floors.......	50"
four floors.....	30		

A footing is designed for the load used for design of the column immediately above the footing. These reductions in live loads recommended by the committee are greater than those given in most old municipal codes. They are recommended for use both in new designs and in investigations of present columns and footings for their ability to support additional floors.

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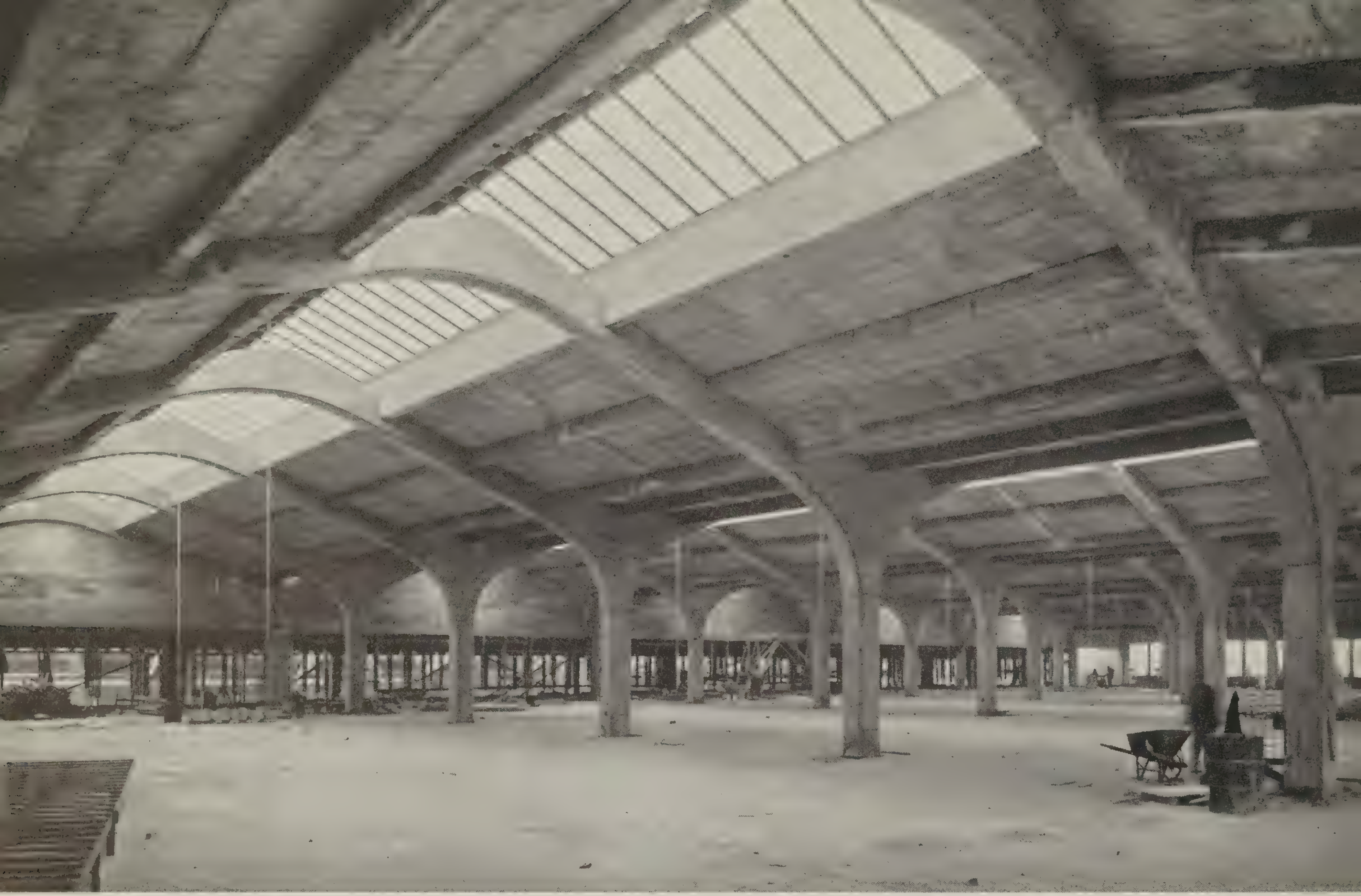
[*] These ratings are reproduced in *Concrete Information ST-47, Fire Resistance Ratings of Building Materials.* They are a valuable aid in comparing and evaluating fire resistance qualities of various materials.

[**] Limestone, calcareous gravel, trap rock, blast furnace slag, burnt clay or burnt shale.

[†] For detailed discussion of one of them, reference is made to *Concrete Information ST-18, Haydite Concrete.*

[‡] Available at cost of 10c from Superintendent of Documents, Government Printing Office, Washington, D.C.



Continuous gabled frames of reinforced concrete support concrete roof slab in the International Amphitheater, Union Stockyards, Chicago. The structure is intended for exhibitions, but the type is equally well suited for manufacturing. Designed by A. Epstein.

13. DETAILS FOR ADDITIONAL STORIES

A most important detail in connection with adding new stories to an old concrete structure concerns doweling of vertical column bars. It has been customary to provide dowels projecting at least 24 diameters above the present roof level. In order to protect the dowels against corrosion, they have been greased or painted and covered with either a wooden box or a block of cast-in-place lean concrete, later to be chipped away.

The drawback in using the dowel detail was that the dowels pierced the membranes provided for insulation and waterproofing. To avoid this defect, some engineers omitted dowels, stopped vertical bars a short distance below top of concrete roof level, and placed pipe sleeves around the top of the bars. It has been found difficult, however, to locate and clean out such pipe sleeves before making them ready for extension of the columns. Another objection is that the butt joint is not considered adequate for transmittal of stress from bar above to bar below.

Welding may be used advantageously for fastening future to present column bars. Top story column bars may be extended 2 to 3 in. above present concrete roof level and covered with a fill which is just thick enough to conceal the top of the bars. The roofing membranes are laid on the fill. When new stories are to be added, remove roofing and fill, and weld new bars to the old bar stubs. Certain lightweight concretes with relatively high insulation value are particularly suited for fill. The fill will be easier to remove if laid on building paper, and it should be reinforced in both directions in order to minimize any tendency it may have to "creep" on the roof slab.

Parapets in buildings of architectural concrete should be detailed so that they may readily be incorporated as part of the future wall to be erected above. Brick parapets in buildings with wall columns must be wholly or in part reconstructed when columns are extended.

Openings made for future use in the present roof should be covered with temporary removable slabs. The customary way is to build the floor with ledges for support of the slab which is cast in a separate operation. The slab will be easier to remove if its contact surfaces are lined with building paper and if the vertical surfaces around the slab are given a slight draw. For removal of a temporary slab, holes may be provided when concrete is placed or may be drilled in it for lifting attachments. Or the slab may be raised from below.

14. EXTENSION OF BUILDINGS

Extension of a building in plan may be carried out with speed and ease if a few simple provisions are incorporated in the original design.

It has been customary to provide for longitudinal extension by means of brackets on the temporary end columns as illustrated in Fig. 35. Under such conditions both columns and footings on the boundary line between old and new construction are designed for the total final load. The bracket bearing surface should be covered with a steel plate, and dowels may be extended from the old construction as indicated. All exposed steel should, of course, be protected against corrosion.

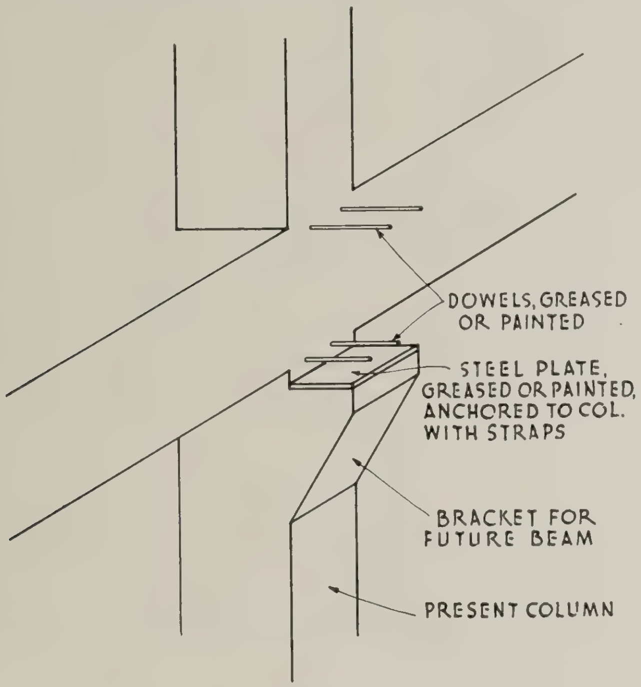

DOWELS, GREASED OR PAINTED
STEEL PLATE, GREASED OR PAINTED, ANCHORED TO COL. WITH STRAPS
BRACKET FOR FUTURE BEAM
PRESENT COLUMN

Fig. 35. Brackets on columns for future extension.

The type of detail described has some drawbacks, especially in buildings with spread footings supported on ordinary subsoil which is loaded nearly to its capacity. Vertical or horizontal movement may cause damage in the joints between the old and new construction. The movements may be caused by unequal settlement of footings and perhaps also by non-uniform volume change.

Settlement of spread footings generally progresses slowly for some time. At the time a new extension is built, footings may have stopped settling under the old building, but they will go through the regular course of settlement under the new building. The result is non-uniformity in settlement of old and new building which causes movement and possible damage to the joints. By keeping the pressure on the soil well within its bearing capacity, differential settlement will be small and the possibility of damage at the joining of new and old construction will be minimized.

It is best, of course, to provide a complete separation between old and new construction by means of expansion joints extending across the entire structure. There should be a complete frame of columns and beams on either side of the expansion joint but no structural connection between the two frames. Movements in the joint will then do no harm.

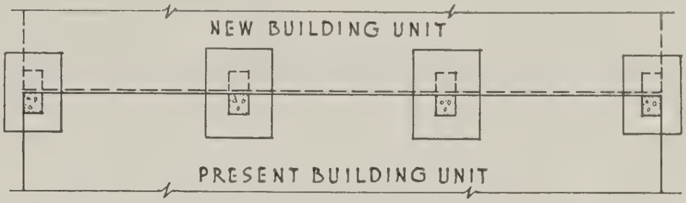


Fig. 36. Customary arrangement of footings designed for expansion of building.

With the usual type of column arrangement, illustrated in Fig. 36, footings at the boundary between old and new construction are built large enough to carry the total final load. Fig. 37 illustrates how to take advantage of the diagonal arrangement of columns discussed in Section 5, see especially Fig. 15. The columns are offset on either side of the expansion joint in Fig. 37, the footing under each column is designed to carry only the load from the column it supports, the bearing pressure is uniform throughout, and the new structure is entirely independent of the old.

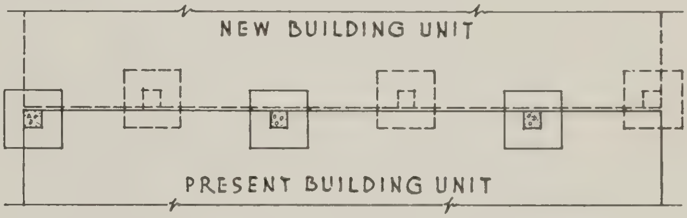


Fig. 37. Footings at expansion joint, columns staggered in old and new building unit.

The temporary end wall in the old building may be left in place to serve as a fire wall when the new building is added, or it may be removed. In the latter case, a concrete block wall will give good service and if properly painted will harmonize well with the appearance of architectural concrete or structural concrete used for spandrels, piers, beams or columns. If the wall is to be removed, upturned spandrel beams should not be used in it. If the wall is to be left in place, however, it may be built as any other exterior wall, but provision should be made for future openings for doors, pipes and conduits.

Expansion joints in floors may be built as illustrated in Fig. 38. The concrete edges are protected with edge angles, the opening is plugged with a compressible material and closed at the bottom with a flexible copper

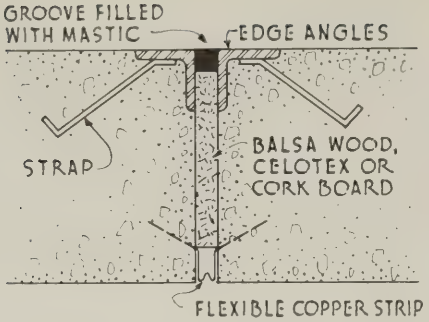


Fig. 38. Expansion joint detail for concrete floor.

strip. The groove formed at the top of the joint is filled with mastic.*

15. EXPANSION ANCHORS

New attachments may be made to old concrete surfaces by means of screws or bolts held firmly in place by "expansion anchors". Many excellent types of expansion anchors are available, but only a few of them will be described here in connection with methods of installation. The types presented are chosen to illustrate a general discussion, and their inclusion does not infer any special recommendation.

Holes slightly greater than the expansion anchors to be used are first drilled into the concrete. An expansion anchor suitable for a screw connection is illustrated in Fig. 39 and for a special type bolt connection in Fig. 40. In both of these anchors, a cone of hard metal with scored surface is placed inside a sleeve usually made of a lead composition. The shape of the lead sleeve is shown cylindrical but may also be conical. The assembly of cone and sleeve is inserted in the hole drilled for it, and a setting tool which is placed against the lead sleeve is given a few sharp blows with a hammer. This makes the lead sleeve expand and stick in the hole. The part to be fastened to the concrete is then placed over the expansion anchor, the screw or nut is attached and pulled up tight. The metal cone is thus forced into the lead sleeve which expands so that it fits tightly in the hole.

The assemblies in Figs. 39 and 40 may be enlarged by including two cones and two lead sleeves. An assembly with two cones, one of which is of lead composition, is illustrated in Fig. 41. A special type of bolt is required for the assembly both in Fig. 40 and in Fig. 41.

Regular machine bolts may be attached to concrete by means of expansion anchors made as illustrated in Fig. 42. The anchor consists of a collar of ductile metal, made very thin at the middle. The depression in the collar is filled with lead so as to give the collar a smooth cylindrical surface. Thus the collar is in effect a double cone similar to the assembly in Fig. 41. The outer cone in both Figs. 41 and 42 is spread by sharp blows on a setting tool placed around the bolt shaft. The inner cone will make the lead sleeve expand when the nut is pulled up tight on the bolt.

The grip obtained by an expansion anchor is approximately equal to the tensile strength of the bolt or screw used. It is not necessary to drill the hole to exact depth, and some lateral adjustment is possible in expansion anchors since the bolts are surrounded by lead composition and therefore can tilt slightly while attachment is being made.

In case a lateral displacement of the bolt must be avoided, a thick circular metal washer is added to the anchor assembly. The washer is slipped over the bolt and lodged securely in the drill hole on top of the anchor but below the floor surface.

Attachment to floors by means of expansion anchors is accomplished easily and rapidly. Even in new construction many builders like to finish concrete floor surfaces without setting any floor bolts. They prefer to come back and drill holes later for expansion anchors in the floor. Expansion anchors may be placed in ceilings and walls also, but here it is preferable to use inserts.

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*For similar details of expansion joints reference is made to the booklet *Concrete Bridge Details* (see Fig. 28) and to *Concrete Information AC-12, Expansion Joints in Concrete Buildings* (see Figs. 6, 7 and 8).

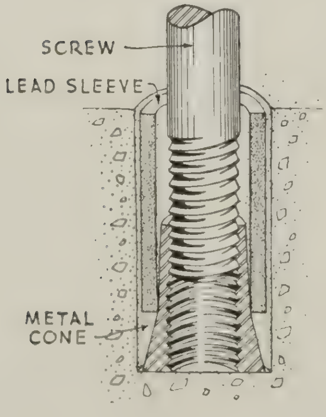


Fig. 39. Expansion anchor for screw connection.

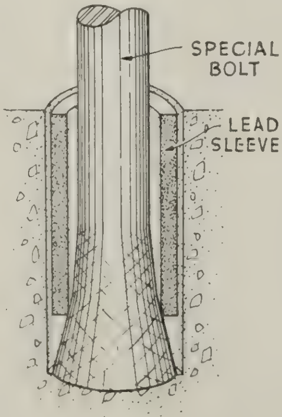


Fig. 40. Expansion anchor for bolt connection.

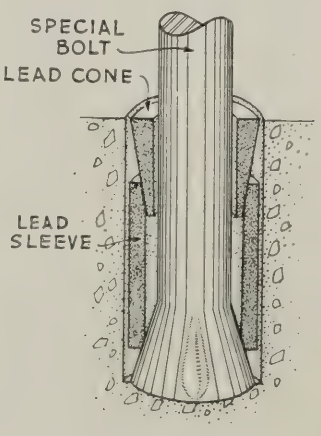


Fig. 41. Expansion anchor with lead sleeve and lead cone.

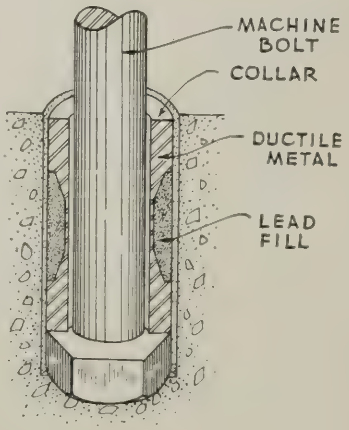


Fig. 42. Expansion anchor for ordinary machine bolt.

16. INSERTS

An economical and practical method of making attachment both to ceilings and to walls is by means of inserts. Inserts may be described as metal casings the inside of which is designed to receive various kinds of screws or bolt heads. The metal casings are usually made so that they can be fastened to the concrete forms, and they are left securely anchored in the concrete when the forms are removed. There are many suitable inserts available, and the fact that only two of them are illustrated here should not be taken to infer any special recommendations.

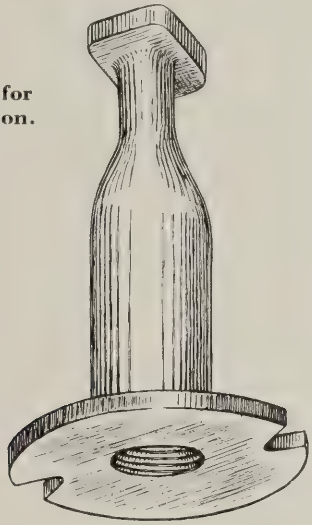


Fig. 43. Insert for screw connection.

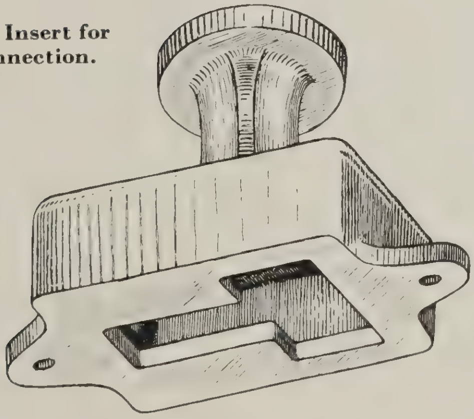
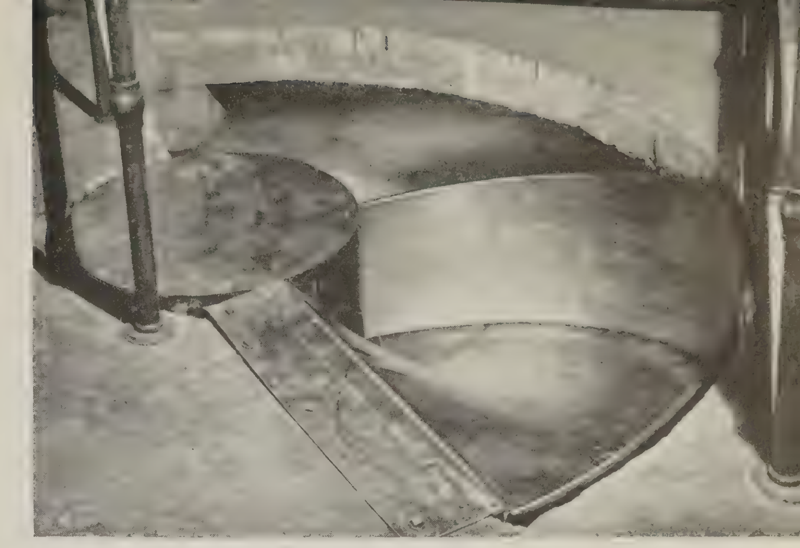


Fig. 44. Insert for bolt connection.

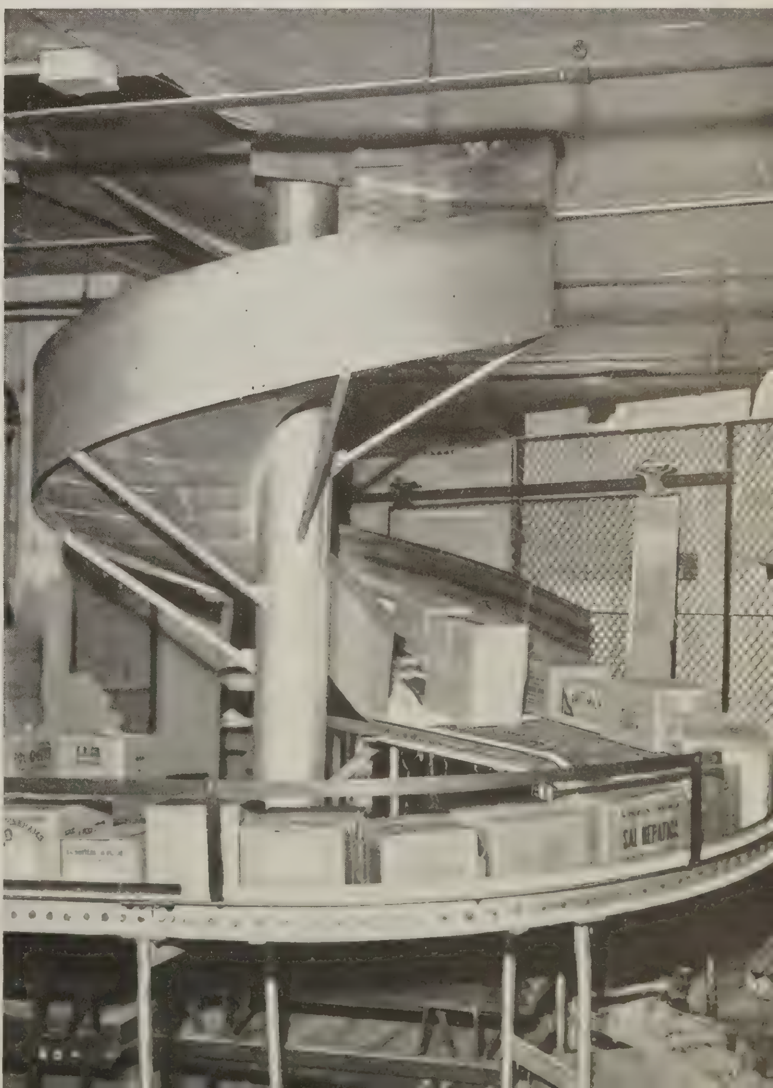
Principal features of inserts are illustrated in Fig. 43, designed for a screw connection, and in Fig. 44, designed for a bolt connection. Both types have the following characteristics in common. One face of the insert is plane and has two small holes or notches for nailing the insert to the form. The nailing is an important feature since it makes attachment easy but dislodgment difficult. The plane face has an opening for insertion of screw or bolt. The opposite face is designed to give the insert secure embedment in the concrete. It must develop enough anchorage so that the insert will not be pulled out under a tension smaller than the capacity of the screw or bolt for which it is designed.



Opening in floor of Albert Pick Company plant is designed for a metal spiral chute. Attachment of chutes and of railing bases may be made speedily by screws or bolts fastened to expansion anchors set in holes drilled in the concrete.

The inside of the insert in Fig. 43 is simply a threaded

Vertical movement of goods by gravity on spiral chutes solves the transportation problem in the Walgreen Company plant, Chicago. Even glass and china are moved speedily, safely and without interruption from floor above to floor below.



Overhead equipment is fastened to ceiling by means of a timber base attached by bolts to the concrete. Attachments can be made rapidly when a sufficient number of ceiling inserts have been provided originally. The building was designed by A. Epstein for Albert Pick Company, Chicago.

hole made for a screw. Sizes larger than 3/8 in. are not usually available. Screw inserts are used for suspension of sprinkler pipes and other relatively light overhead equipment. Since no lateral adjustment is possible in screw inserts, hangers for pipe lines should be made adjustable in both horizontal and vertical directions. A swivel and split-ring type of hanger gives good service.

Inserts of the type illustrated in Fig. 44 are designed for bolt sizes up to 1 in. Some of them take a regular bolt head while others require bolt heads of special shape. In general, the bolt head is inserted through the larger part of the opening and then moved horizontally so that the bolt shaft extends through the slot while the head bears on the inside edges. It is desirable that lateral movement of the head should be prevented after the attachment has been completed. The bolt heads may be lodged securely in various ways. A certain amount of lateral adjustment of the bolt is possible within the insert. Some slots are made up to 6 in. long, and a bolt may be placed anywhere within this distance.

It is good practice to seal or grease the inside of inserts before they are placed in order to keep out cement paste and to avoid corrosion.

Under certain circumstances, continuous "anchor slots" are used which incorporate the same anchorage features as inserts but make it possible to make attachment at any point along the slot. They are especially useful when placed in concrete columns or walls for anchorage of partitions or furring.

Attachment of furring to concrete walls may be made by means of anchor slots, wire loops, wood plugs, nailing inserts, strap anchors or by special patented devices.*

It is good practice to use plenty of inserts in all ceilings in factory buildings so that attachments can be made anywhere at any time. It is recommended to place an insert every 4 ft. in both directions. If this is done, it will seldom be necessary to drill holes in the ceilings for expansion bolts.

17. PIPE SLEEVES IN NEW CONCRETE FLOORS

Expansion anchors and inserts, discussed in Sections 15 and 16, furnish useful and convenient ways of providing for equipment of non-permanent nature, that is, equipment which is not essential to the operation of the building itself. Permanent equipment such as sprinkler system, plumbing and heating pipes should preferably be installed by means of pipe sleeves in the concrete floors.

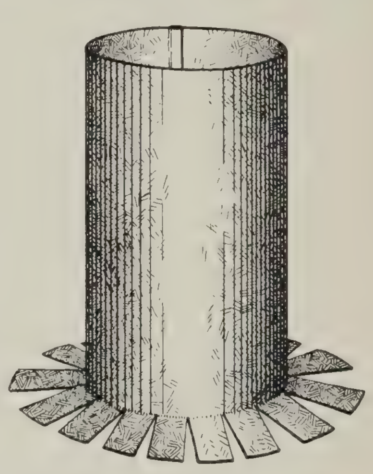


Fig. 45. Pipe sleeve for circular hole in concrete floor.

Small circular openings through concrete floor slabs may be made by means of ordinary stovepipe. One end of the pipe is slotted and spread out to form a base as illustrated in Fig. 45. The base is nailed firmly to the slab forms, and the pipe is filled with sand before the slab is concreted.

In some instances, such as in roofs designed for use as future floors, it may be desirable to provide for a future opening without having a hole in the present slab surface. In order to do this, make the pipe 1 to 2 in. shorter than the slab depth and cover the top of the pipe with a cap. The hole may then be broken through easily whenever required.

Spaces between pipe sleeves and pipe risers, and also holes provided for future use should be plugged with an elastic compound to prevent leakage.

The use of small pipe sleeves for through bolts is illustrated in Fig. 46. Standard bolt heads will not cause interference if they are on the ceiling; but on floors, bolts with button heads should be used.

Cast iron pipe is often used, especially for sprinkler pipe risers. Such risers are placed as close as possible to

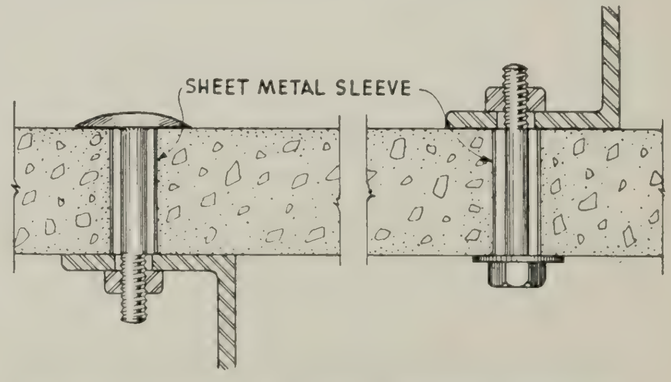


Fig. 46. Pipe sleeves for bolting permanent equipment.

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*For details and further discussion of furring see *Concrete Information AC-16, Furring for Architectural Concrete Walls.*

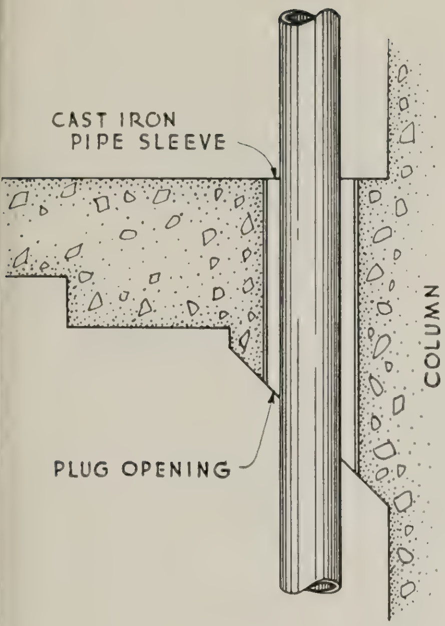

Fig. 47. Cast iron pipe sleeve at columns.

columns and therefore extend through the drop panel and capital of flat slab construction. One end of the pipe sleeve is shaped as shown in Fig. 47 to conform to the contour of the capital. The diameter of this opening should not exceed one-twentieth of the average panel length in flat slab construction.

Even where no pipe risers are required at columns in the original layout, it is still a good plan to provide one large pipe sleeve at every column as illustrated in Fig. 47. Since the opening should be plugged anyway, it is even better to terminate the cast iron sleeve about 2 in. below the floor surface, provide it with a cap, and let the concrete cover the top of the cap.

18. NEW HOLES THROUGH OLD CONCRETE SLABS

The most common method of making new holes through old concrete slabs is by use of star drills. Hand drilling is used mainly for small holes down to ¼-in. diameter, but power drilling is necessary for the larger holes up to 2-in. diameter. Star drills are seldom used for diameters larger than 2 in., and they will not cut through reinforcing bars.

If in drilling a hole the operator hits a bar, he should remove the drill to another point about 2 in. away from the first hole. If the second hole is drilled at any one of the points marked *A* in Fig. 48, there is an even chance that the drill will hit a bar also the second time. It is better to move the drill in the diagonal direction to any one of the points marked *B*, where the probability of hitting a bar is slight.

In drilling from above through the entire depth of the slab without taking special precautions, the concrete may spall on the underside as illustrated in Fig. 49. This can be avoided by first drilling into the ceiling, to a depth of about 2 in., a hole slightly larger than the hole which is drilled from above. This may be a cumbersome procedure, and it will be easier to drill the entire hole from above, exerting sufficient pressure against the ceiling at the hole during the drilling to prevent spalling. One way to do this is by wedging a shore between the ceiling and floor as indicated in Fig. 49.

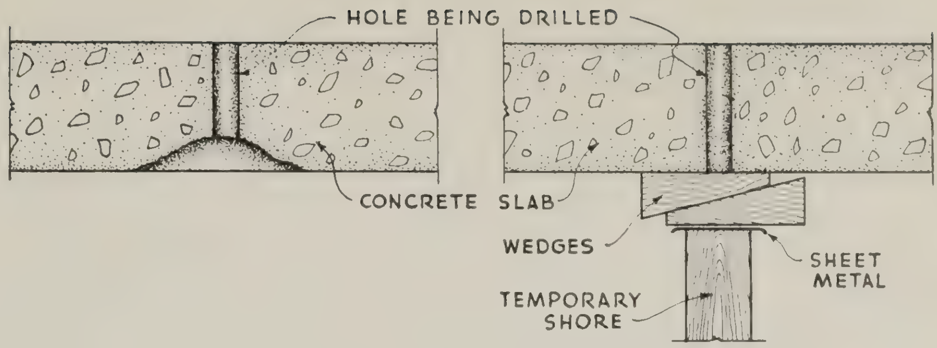

Fig. 49. Drilling through concrete slab.

For larger holes, the method of "coring", used successfully in highway work, may be employed. The procedure developed for highway work is essentially as follows. The "drill" consists of a seamless steel tubing, which is available in various diameters. One end of the tubing is closed with a metal disk to which a drive shaft is attached. A notch is cut in the other end as illustrated in Fig. 50, but the cutting edge is neither sharpened nor treated in any other way. The actual cutting is done not by the edge of the tubing but by small "shot" made of chilled steel. To get the cutting started, it is necessary to pour the shot into a circular groove formed as illustrated in Fig. 50. The concrete must be kept wet in the cutting groove. The tubing is rotated at a fairly slow rate of speed between 50 and 100 r.p.m. It is possible to cut through reinforcing bars in this way. Holes cut by the coring procedure described are generally made from 4 to 6 in. in diameter, but

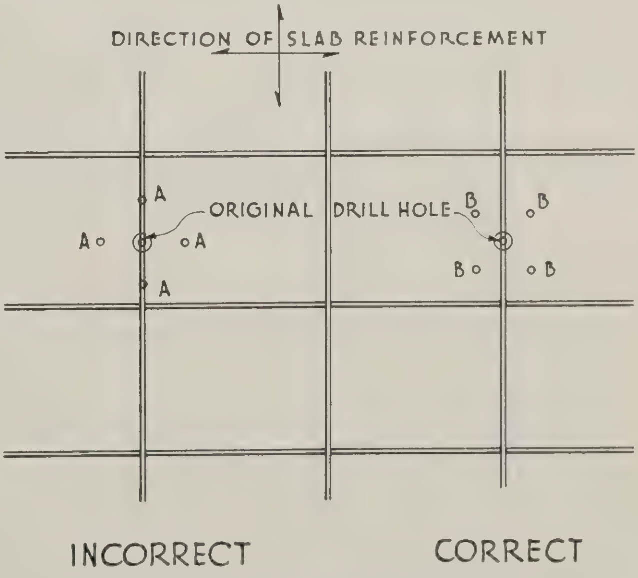

Fig. 48. Locating drill holes to miss reinforcement in concrete floors.

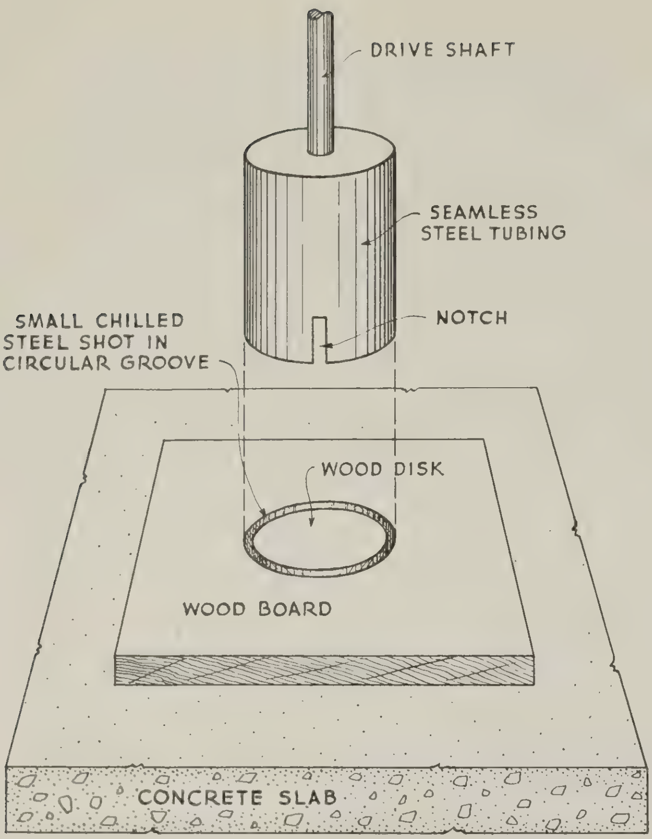

Fig. 50. Coring through concrete slab.

larger holes may be made with proper equipment.

Openings may also be made through concrete slabs by means of a rotating saw consisting of a circular steel disk with a carborundum cutting edge. The steel disk is rotated at a high speed, about 5,000 r.p.m., and cuts a groove while being moved slowly back and forth on the concrete. It will cut through reinforcing bars. The depth of the groove depends upon the diameter of the cutting disk. In cutting a rectangular opening as in Fig. 51, it is well first to drill or core one hole at each corner of the opening and then saw through the slab.

19. INSTALLATION OF ELECTRIC CIRCUITS

A distinction is often made in factories between electric circuits for permanent and for non-permanent purposes. Permanent installation includes lights, fans, elevators, power-operated doors and column outlets. Conduits and outlet boxes for permanent installation are set by the electrical contractor before the concrete is placed. They are nailed to the form boards and remain embedded in the concrete when the forms are stripped.

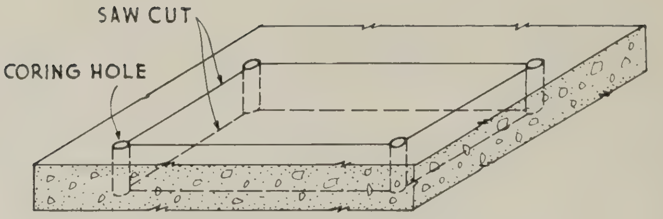

Fig. 51. Cutting large opening in concrete slab.

Power lines for machines may be run in exposed circuits installed by the plant electrician any time after completion of the concrete structure. The plan of running power lines concealed in the structure may give better appearance when the structure is new, but there is likely to be new out-croppings of exposed lines whenever the production layout is changed. The lines may as well be exposed from the beginning. They can be attached to ceiling inserts or to small expansion anchors.

Some designers run ducts for power lines the full length of the factory building along the inside of the wall. The ducts may be placed at the base of the wall, but in flat slab construction it may be better to attach the duct to the ceiling. Fig. 52 illustrates this arrangement which is particularly satisfactory when the spandrel beam is of uniform width. The duct should have detachable bottom or side so that the plant electrician at any time and at any point can open the duct and make the desired connection. The main and the cross ducts illustrated may be attached to ceiling inserts.

In factory offices with many electrically operated small machines the exposed ceiling ducts with wire dropped down to working level may be objectionable. However it is possible to install under-floor ducts in a 2-in. concrete topping. The ducts are concealed, and connections can readily be made at any time.

A good rule to follow is to install lamp outlets not farther apart than the height from floor to ceiling, and also to provide D.C. and A.C. power panels on alternate columns. It is essential that the wire be of suitable size in order to avoid the expense of re-wiring a factory building. A 100-watt lamp may be adequate in a warehouse, but it may take 300 to 500-watt lamps for fine machine work. Opportunities for improvement of artificial illumination by painting the concrete ceilings should be carefully considered.*

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*For details and recommendations reference is made to *Concrete Information ST-1, Painting Concrete.*

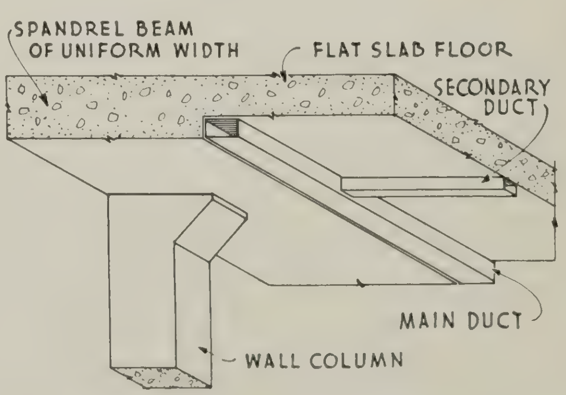


Fig. 52. Ducts for electric conduits attached to flat slab ceiling.

GARAGES

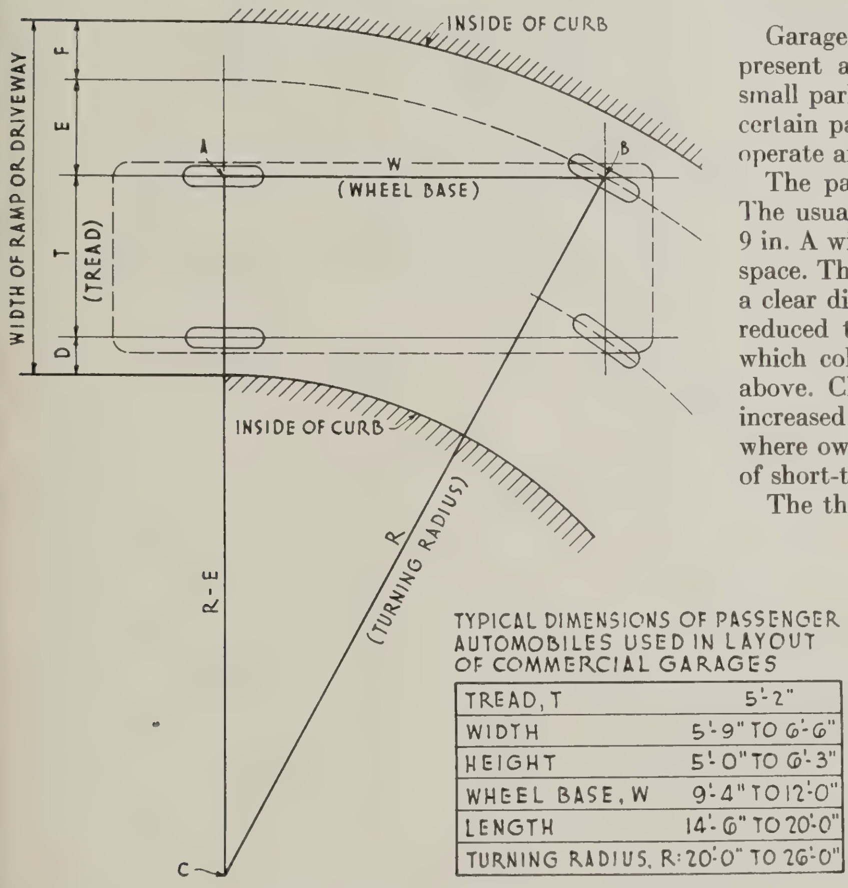
20. DIMENSIONS OF AUTOMOBILES

FROM year to year, the manufacturers of automobiles make minor changes in dimensions of new car models, but in general the dimensions in Fig. 53 represent a fairly uniform standard practice which may be used for layout of garages.

The tread, T, is practically the same for all cars. Other dimensions vary from model to model, usually within the limits given in Fig. 53. Width, height and length are overall dimensions of the car body itself. Wheel base and turning radius are the dimensions marked W and R in the diagram.

It is often necessary to make a study of a curved ramp or driveway in garages in order to establish minimum dimensions for width and curvature. Fig. 53 contains a sketch showing how to determine such dimensions. The heavy lines are sides in a right-angle triangle, in which W and R are known.

Determine $R - E = \sqrt{R^2 - W^2}$, and insert known values for R and W. Then establish width and curvature of ramp on basis of R, E, T and the clearances, D and F, that are considered necessary for operation. D = 1 ft. and F = 1 ft. 6 in. are considered minimum,



TYPICAL DIMENSIONS OF PASSENGER AUTOMOBILES USED IN LAYOUT OF COMMERCIAL GARAGES

TREAD, T	5'-2"
WIDTH	5'-9" TO 6'-6"
HEIGHT	5'-0" TO 6'-3"
WHEEL BASE, W	9'-4" TO 12'-0"
LENGTH	14'-6" TO 20'-0"
TURNING RADIUS, R:	20'-0" TO 26'-0"

Fig. 53. Dimensions of automobiles and layout of curved ramps.

21. LAYOUT OF PARKING UNITS

Garages to be erected on property of limited extent present an important problem in layout. Numerous small parking units, or car stalls, must be arranged in certain patterns so that the finished garage is easy to operate and profitable to its owner.

The parking unit itself is fairly well standardized. The usual width of parking space for one car is 6 ft. 9 in. A width in excess of 7 ft. is considered a waste of space. Three cars parked between two columns require a clear distance of 20 ft. 3 in. This dimension may be reduced to a minimum of 20 ft. in lower stories, in which columns are likely to be larger than in stories above. Clear distance between columns is frequently increased to 21 ft. for a group of three cars in garages where owners park their own cars or where parking is of short-time duration such as in garages for shoppers.

The three-car bay is the unit that is used most frequently, and permits the parking of two trucks in a bay. Certain advantages are claimed for a two-car bay, but the tendency is to use two and four-car bays only where necessary to make parking units fit ramp layout or property lines.

The depth of a parking unit is usually 15 ft., and aisles between parking units are 20 ft. Two rows of cars with one intermediate aisle require a total width of 50 ft. as illustrated in the first sketch in Fig. 54. The 50-ft. dimension is the clear distance between walls or spandrels.

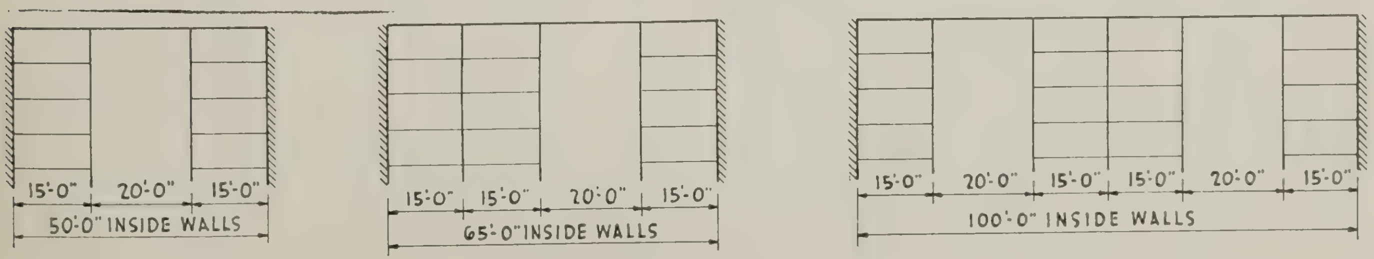


Fig. 54. Layout of parking units.

These dimensions are a little cramped for long cars. Such cars may conveniently be parked at ends of aisles where encroachment on aisles is of little consequence.

The second sketch in Fig. 54 shows the type of parking arrangement that may be used for a 65-ft. clear width. There is single parking on one side of the aisle but double parking on the other side. In other words, one-third of the parking area may not always be readily accessible. Yet, the arrangement may work well in some instances, and in others there may be no other choice for a lot of such limited width.

The third sketch in Fig. 54 shows four rows of parking, a scheme suitable for a 100-ft. clear width. All parking spaces face an unobstructed aisle. This layout is commonly used, but there are instances in which all three layouts illustrated may be combined with each other or with other layouts not shown. Each site presents a different problem in layout.

Concrete ramps carrying truck traffic from floor to floor in the Chicago Carton Company plant provide easy and uninterrupted vertical transportation of materials. The concrete ceiling has been painted to improve illumination on the ramp.

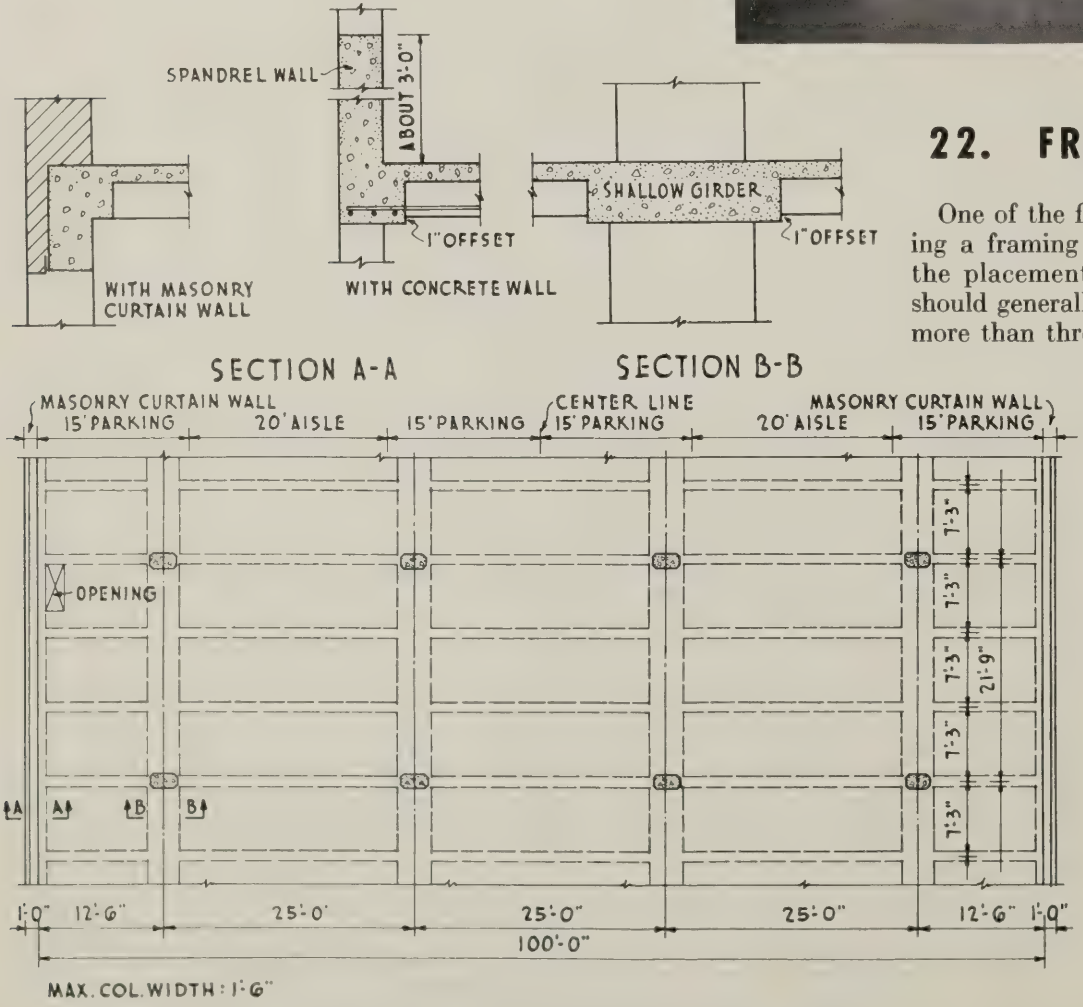


Fig. 55. Beam and girder framing, 100-ft.-wide garage.

22. FRAMING PLANS

One of the first problems in developing a framing plan for floors concerns the placement of columns. Columns should generally be spaced to allow not more than three cars in each bay. The column centerline may be set back 2 to 3 ft. from the aisle, and the column width should not be made more than 1 ft. 6 in. If necessary, the column cross-section may be oblong. Column corners should be beveled or preferably rounded. Guard curbs are not needed around column bases, but a thin guard plate is useful around the bottom of columns up to just above the level of bumpers.

The placement of columns in Fig. 55 represents a typical layout for a 100-ft.-wide garage. The column spacing is 21 ft. 9 in. in the longitudinal direction, allowing a clear width of 20 ft. 3 in. for three cars, and 25 ft. in the transverse direction. The use of bays with equal width has the advantage of simplifying the construction of forms and the fabrication of reinforcement. After having established the panel size of 21 ft. 9 in. by 25 ft. 0 in., the choice of floor framing has been limited to certain types, three of which will be discussed.

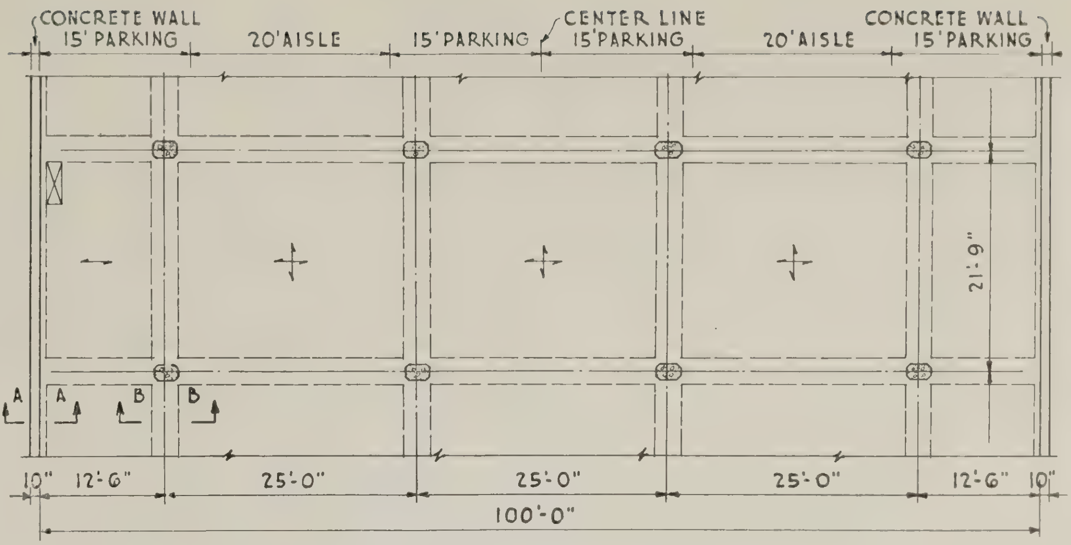


Fig. 56. Two-way solid slab framing, 100-ft.-wide garage. *A-A* and *B-B* similar to Fig. 55.

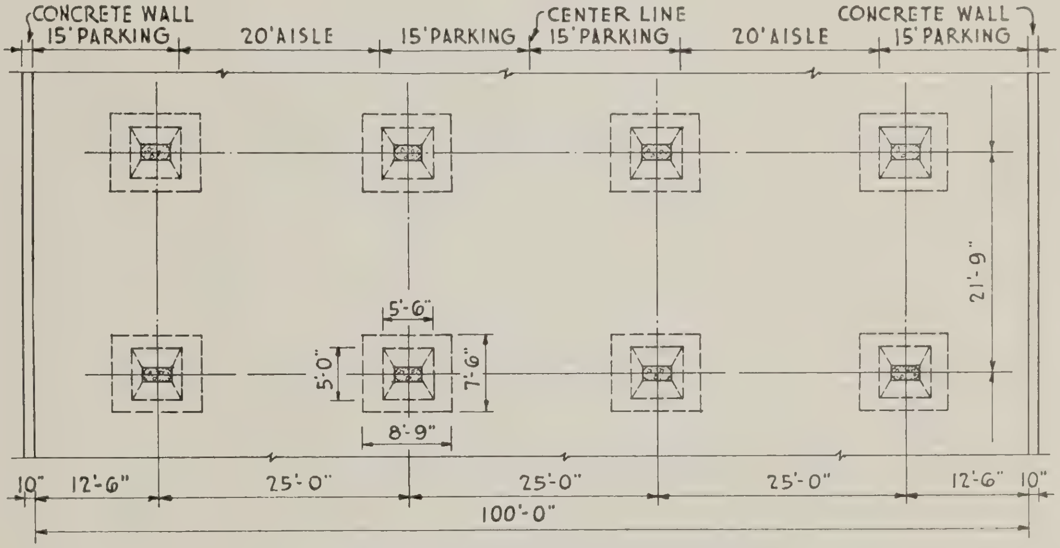


Fig. 57. Flat slab framing, 100-ft.-wide garage.

Fig. 55 shows a beam and girder framing. The floor slab has its main reinforcement in the longitudinal direction and spans between beams supported on girders. It is advantageous to make the girders the same depth as, or 1 in. deeper than, the beams. The 1-in. difference in depth is preferred because interference of bottom bars is then avoided. The shallowness of the girder cuts down the height of the structure. The bays outside the exterior columns are cantilevered from the interior floor construction. Spandrel beams and wall construction are supported on the ends of the cantilever bays.

The same panel size of 21 ft. 9 in. by 25 ft. 0 in. is used in Fig. 56. The ratio of long to short span, 1.15, is suitable for a two-way solid slab floor framing as illustrated. The beams shown are wide and shallow, but deep narrow beam webs may of course be substituted. In both cases, the longer beams should preferably be 1 in. deeper than the shorter beams. The outer narrow bays are here, as in Fig. 55, cantilevered and support spandrel beams as well as other wall construction.

The third floor framing illustrated for a 100-ft.-wide garage is a two-way flat slab floor system. General features of flat slab design have been discussed in Section 3. The three center bays in Fig. 57 may be designed as typical interior panels, and the narrow outer bays are designed as cantilevers supporting their own and the superimposed load in addition to the load of the wall construction.

If no columns are desired in the parking space, the layout in Fig. 58 gives a good framing. It has three rows of columns, one in each of the two walls and one along the centerline of the building. The column spacing in the longitudinal direction is shown as 20 ft. 3 in. The spacing should be increased to 21 ft. where cars are parked by their owners.

Since the girder span is relatively short in Fig. 58, the girder depth can be made equal to or, preferably, 1 in. deeper than the beam depth. The layout is shown with three beams for each bay. A layout with four beams per bay may sometimes be better. Tapered ends

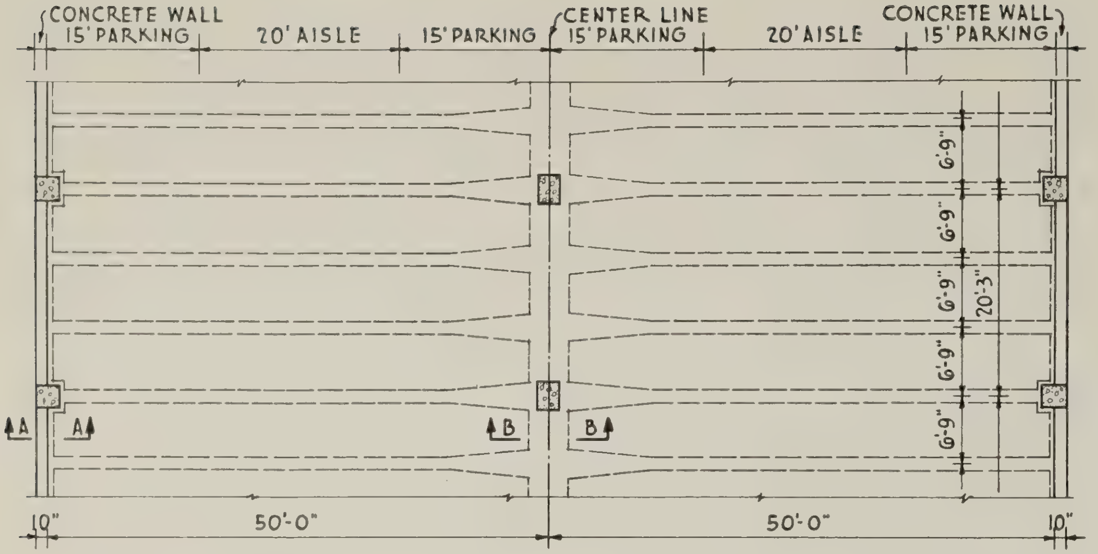
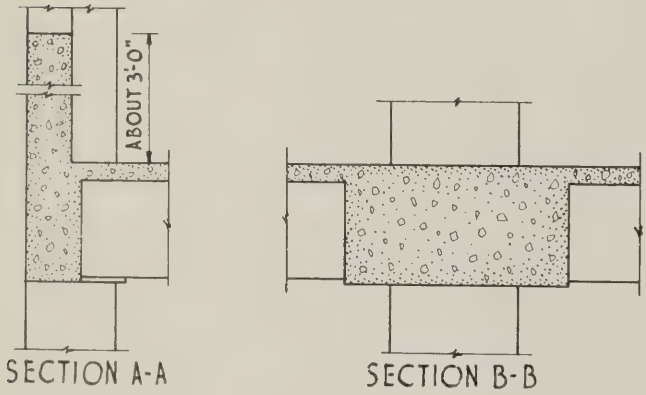


Fig. 58. Beam and girder framing, two 50-ft. spans.



are often required on beams, especially at the center girders where shear and compression may be high.

In some instances, a two-span rigid frame layout may also give a satisfactory solution for framing in a 100-ft.-wide garage with three rows of columns. Further discussion of this type of framing will be given in connection with a 50-ft.-wide garage.

Fig. 59 shows a 50-ft. garage with a row of columns in each wall. The spacing of columns is shown as 20 ft. 3 in. The floor design system is a joist construction formed by means of tapered metal pans. The joist floor system is supported on girders which are cast integrally with columns at both ends. Girder and columns form a rigid frame and should be designed as such.* A horizontal thrust is created by the rigid frame at the base of its vertical members. The thrust, giving tension in the floor members, should be taken care of in the floor design. Columns should, of course, be designed for combined bending and axial load.

A clear story height of 8 ft. is ample for ordinary cars, but more is required for trucks. A good arrangement is to use 8-ft. clear height in upper stories, but to use greater height in the first story where trucks may then be parked.

A superimposed load of 100 p.s.f. is ample for all passenger cars, and 150 p.s.f. is sufficient for most trucks.

23. RAMPS

In multi-story garages, a car is generally moved from floor to floor under its own power on ramps. Types of ramps may be grouped under the following general headings:

Ordinary incline, straight-run
Curved or spiral
Staggered floor
Pitched floor
Combinations, such as straight and curved combined

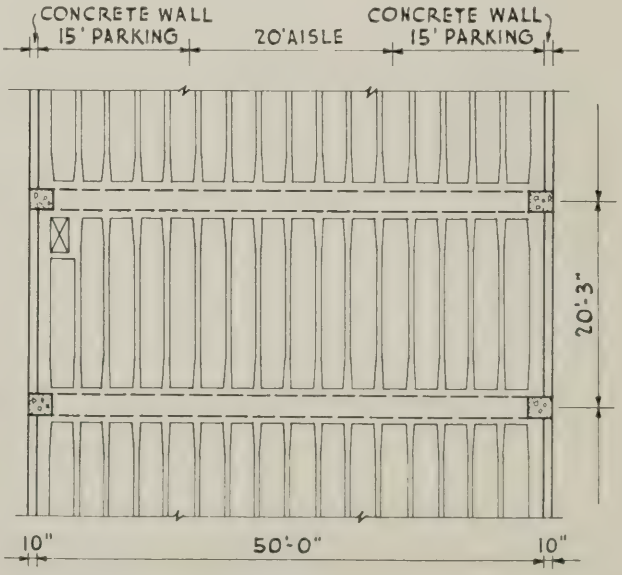


Fig. 59. Rigid frame layout with metal pan floor.

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*For analysis of rigid frames, reference is made to *Concrete Information ST-41, Concrete Beams and Columns with Variable Moment of Inertia,* and *ST-42, One-Story Concrete Frames Analyzed by Moment Distribution.*

Many patents have been taken out on ramp systems and ramp features. For a good discussion of this subject, reference is made to "The Layout of Automotive Buildings" by H. F. Blanchard, published in the *Architectural Forum*, March, 1927.*

Determination of width and curvature of circular ramps has already been illustrated in Fig. 53. It should be noted that such ramps cannot be built in garages that are narrower than 60 ft., a dimension that is established by the turning radius of a car.

The ramp grade is made anywhere from 12 to 20 per cent, the average being 15 per cent. Ramps should have curbs at the edges, and it is good practice to make the curbs conspicuous by painting them black and white.

Ramps should, of course, have suitable banking and easement curves. The surface should be a rough, broomed finish, or a non-slip aggregate finish may be used. Transverse grooves in the top surface of either ramps or floors are not recommended anywhere in garages. The grooves may collect oil or grease, which tends to make the surface slippery.

The structural framing of ramps depends largely on type of ramp and layout of garage. It is customary to use solid concrete slab on beam construction. The building of forms requires superintendence by an experienced man. Placing of reinforcement and concrete is similar to that for pitched roofs. Good care should be given to mixing and placing concrete, but there are no unusual features involved.

24. STRUCTURAL DETAILS

During winter months it often happens that cars are driven into a garage while they are covered with ice and snow which melts in the warm garage. Water covering an improperly constructed floor may then leak through small cracks and drip down on cars parked below. This trouble can be avoided by giving proper attention to structural details. The discussion that follows applies to all exposed concrete floors through which leakage must be avoided.

Cracks at construction joints sometimes open enough to permit leakage. This can be prevented very largely by proper details. It is recommended that construction joints in garages should be marked plainly on the drawings, and that no joints other than those shown should be permitted. Extra reinforcement should be placed at right angle to the joint and should extend at least 50 diameters on each side. The area of the extra reinforcement should be not less than 0.003 times the concrete area in the joint. This precaution will serve to minimize cracking, but it may be desirable to require also that a ½-in.-deep "cut" be made in the top surface of the concrete in the joint (see sketch, Fig. 60). If this is done, and a crack should develop in the joint, leakage may be prevented by simply calking the cut in the joint. Another solution is to avoid construction joints altogether or to place them where leakage can do no harm.

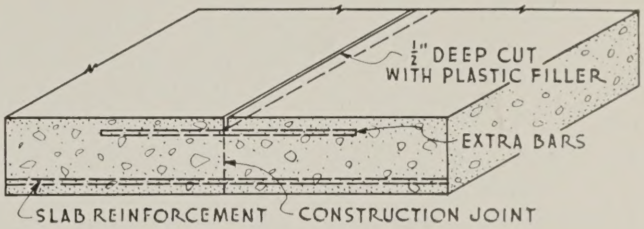

Fig. 60. Construction joint in garage floor.

Cracks caused by negative moments are less likely to open sufficiently to permit leakage than construction joints. A "negative" moment creates tension in the top surface of the floor. Top bars for negative moments are frequently either too short or too small, or are omitted entirely at end supports. Section *A-A* in Fig. 61 illustrates these defects. If a top bar slips (too short) or yields (too small), a large crack may open through the slab and permit leakage. Fig. 62 illustrates the correct and the incorrect way of detailing bars at spandrel beams. Leakage will be avoided by providing top reinforcement with sufficient area and length.

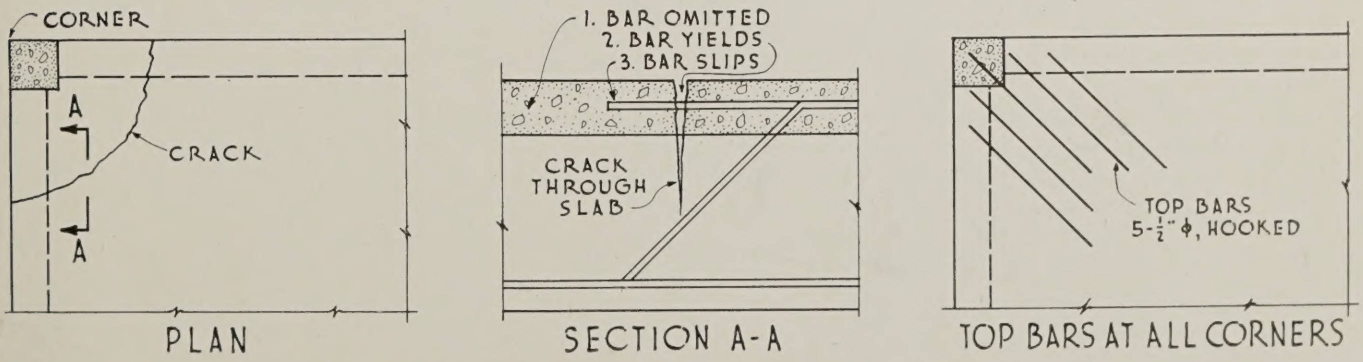

Fig. 61. Cracks caused by negative moments.

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*For further references, attention is called to the following publications which deal not only with ramps but also with other items of importance in design and layout of garages:

Garages, Standards for Design and Construction, *Architectural Record*, Feb., 1929, p. 178.
Ramp Problems in Garages, by K. F. Jackson, *Architectural Forum*, April, 1928, p. 599.
Automotive Buildings Reference Number, *Architectural Forum*, March, 1927.

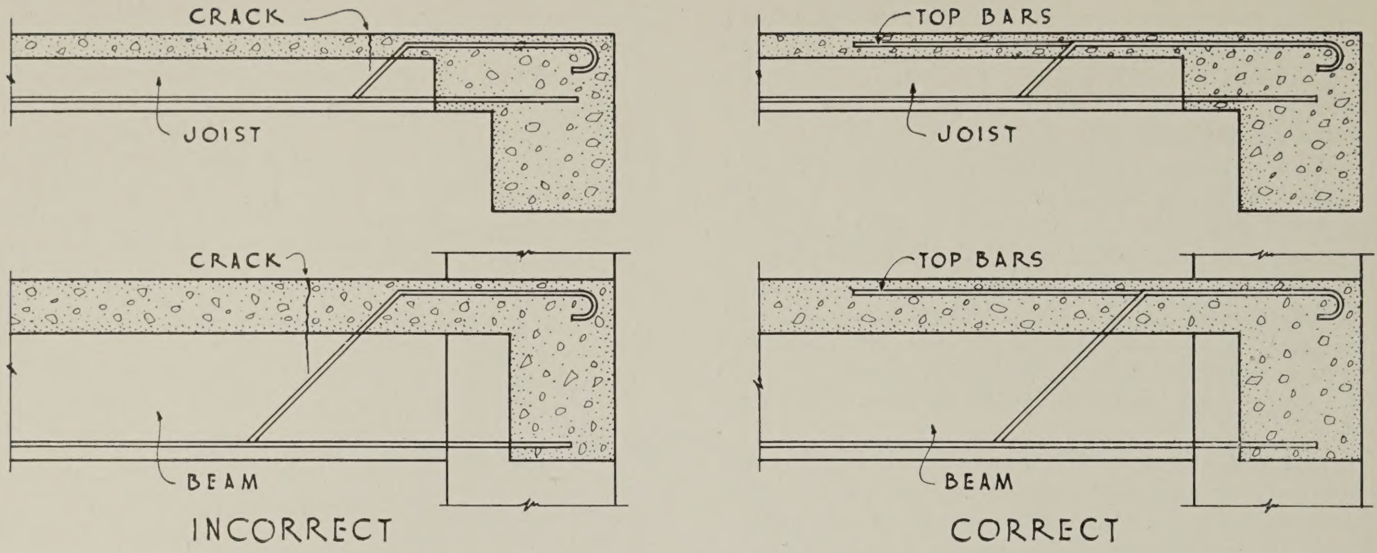

Fig. 62. Correct and incorrect bar details at spandrel beams.

The possibility of cracks at the corners of openings in floor slabs can be minimized by placing diagonal bars at each corner. Each group should have not less than three ⅝-in. round bars 5 ft. long. The designer should study the framing plan together with all openings through floors with the view of providing extra reinforcement across planes that may crack.

Where the top slab of metal pan floor construction is made too thin and under-reinforced, cracks may occur. It is recommended for such floors that the top slab should be not less than 3 in. thick and reinforced with not less than ⅜-in. round bars spaced 12 in. on centers. The bars should be placed in the top of the slab.

25. ELEVATORS, STAIRS AND ROOFS

As has already been mentioned, circular ramps cannot be built in garages with a width less than about 60 ft. In small garages, say 50 ft. wide, the use of elevators may be fairly satisfactory for moving cars up and down. This is especially true in service garages and in other garages where the peak load is small.

Car elevators are usually made 10 ft. wide, 20 ft. long and 8½ ft. in clear height. They are often placed in the back of the garage, and it may be convenient or even necessary to have a turntable in front of the elevator.

Passenger elevators and stairways may be placed in a corner or in any other convenient bay. Fig. 63 is a typical layout showing how to accommodate both elevator and stairway in a bay two cars wide. The spacing of columns adjacent to the stairs should be 15 ft. center to center. A 36-in. width is usually sufficient for the stairways. Concrete block walls are indicated for the enclosure, and steps as well as landings may be of solid slab concrete construction.

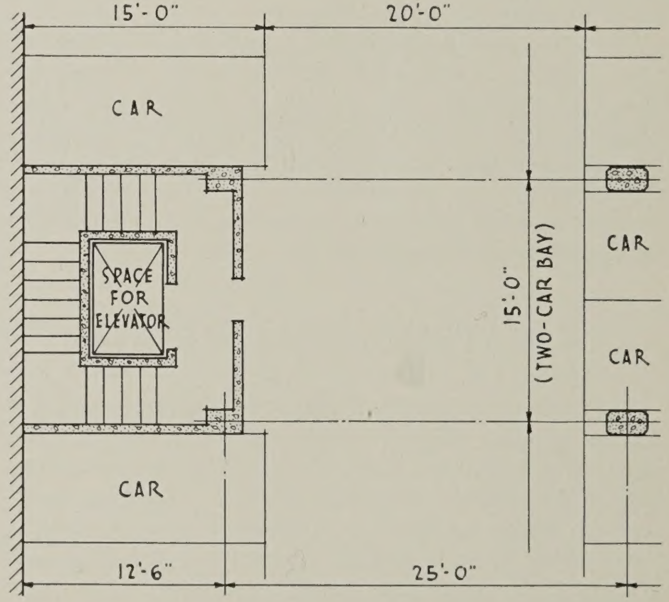

Fig. 63. Layout for passenger elevator and stairway.

It is often a good plan to provide for parking on the roof. This may give an extra source of income, and it may also facilitate the construction of additional stories if the ramp to the present roof level has been built beforehand. The roof slab may be covered with regular 5-ply roofing. The roofing may be protected with a 3-in. concrete slab reinforced with mesh and laid in 20x20-ft. squares. Joints between squares should be ¼ in. wide with a plastic joint filler.

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